SULTANIC AGRICULTURAL SOCIETY

THE INSECT AND RELATED PESTS OF EGYPT

VOLUME I

THE INSECT AND RELATED PESTS INJURIOUS TO THE COTTON PLANT

PART I

THE PINK BOLLWORM

BY

F. C. WILLCOCKS

ENTOMOLOGIST TO THE SULTANIC AGRICULTURAL SOCIETY

CAIRO

PRINTING-OFFICE OF THE FRENCH INSTITUTE OF ORIENTAL ARCHÆOLOGY

1916

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THE
INSECT AND RELATED PESTS
OF EGYPT

BEING

AN ACCOUNT OF THE LIFE-HISTORY AND HABITS OF THE INSECTS,
MITES AND TICKS, INJURIOUS TO EGYPTIAN AGRICULTURAL AND HORTICULTURAL CROPS;
FRUIT AND FRUIT TREES; ORNAMENTAL PLANTS AND SHADE TREES;
DOMESTIC ANIMALS; STORED PRODUCTS AND SEEDS;
BUILDINGS; FURNITURE AND CLOTHING, ETC.; AND BY DIRECT ATTACK OR AS CARRIERS
OF DISEASE, TO MAN.

TOGETHER WITH

SUGGESTIONS FOR THEIR CONTROL AND AN ACCOUNT OF THEIR NATURAL ENEMIES.

BY

F. C. WILLCOCKS
ENTOMOLOGIST TO THE SULTANIC AGRICULTURAL SOCIETY.

THIS REPORT IS RESPECTFULLY PRESENTED

TO

HIS HIGHNESS PRINCE KEMAL-EL-DINE

PRESIDENT

OF THE

SULTANIC AGRICULTURAL SOCIETY

PREFACE.

The present volume is, it is hoped, the first of three of a report on *The Insect and Related Pests of Egypt,* a work long under consideration, but the writing of which has had to be postponed many times owing to circumstances largely beyond my control. Originally it had been intended to publish an account of the insect and related pests of the cotton plant in a single part to form Volume I of the complete report, but the great importance assumed by the Pink Bollworm during recent years as a pest of cotton in this country has made it imperative that a detailed and illustrated account of what is known up to the present time about this insect scourge should be put into print without further delay.

In Part II of Volume I the other well-known pests of the cotton plant — the cotton worm, the ordinary bollworm, the cutworm, the aphis, etc., as well as the insects and mites of minor importance which occur on this plant, will be delt with in detail and fully illustrated. Volume II will include an account and suggested methods for their control of the insect and related pests of agricultural and horticultural crops other than cotton; fruit and fruit trees; shade trees; ornamental plants and shrubs; domestic animals; household pests; and insects directly injurious to man by biting or stinging him or acting as carriers of disease germs. All of these creatures and their work will be fully illustrated by coloured plates and photographs.

In the pages of this volume I have endeavoured to give so far as is known to me, a detailed account of what is known and is not known about the pink bollworm in Egypt and in other countries where it

occurs. It must not be thought, however, that the least suspicion of a claim is laid to have produced a complete account, in the sense that there is little or nothing more to be known or said about this pest. Before anyone is in a position to even attempt such an ambitious project, years of study will have to be given to the subject — not by one observer, but by many. The present report must be regarded in the light of only a preliminary discussion of the pink bollworm problem in Egypt, giving the writer's view of the question. No doubt further researches may necessitate modification of some of the opinions now held and expressed herein, and the abandonment or addition of others.

I will take this opportunity of expressing my sincere thanks to my assistant Said Effendi Bahgat for the help which he has contributed to the production of this report. I have many other acknowledgments to make, but these can be made more appropriately in the later volumes.

My sincere thanks are due to Mr. H. C. Jefferys, Consulting Agriculturist to the State Domains Administration, for the many valuable opportunities he has given me to study the pink bollworm amidst the large areas of cotton grown at Sakha. I must also express my indebtedness to the State Domains Administration for the many courtesies received.

Cairo, August 1st, 1915.

F. C. Willcocks.

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ERRATA.

Page 14, line 11, *for :* brumper, *read :* bumper.

Page 18, line 7, *for :* ensues, *read :* ensures.

Page 51, line 15, *for :* 12 plants, *read :* 24 plants.

Page 59, line 2, *for :* losses, *read :* loses.

Page 69, last line but one, *for :* date, *read :* data.

Page 81, line 17, also pages 320 and 321, *for :* Crocidosema plebiana, *read :* Crosidosema plebeiana.

Page 97, line 5, *for :* and, *read :* or.

Page 105, line 9, *for :* area attached, *read :* are attached.

Page 107, line 5, *for :* hinderence, *read :* hinderance.

Page 111, line 21, *read :* wind itself up again.

Page 151, line 20, *for :* draw, *read :* drawer.

Page 152, lines 4 and 5, *for :* draw, *read :* drawer.

Page 152, line 10, *read :* were trapped finally.

Page 173, line 2, *for :* of danger, *read :* a danger.

Page 174, line 13, *for :* surving, *read :* surviving; line 18, *for :* pupa on, *read :* pupa stage on.

Page 185, line 20, *for :* In the seed, *read :* From the seed.

Page 201, line 8, *for :* date, *read :* data.

Page 210, line 7 from bottom, *delete* to.

Page 218, line 1, *for :* might, *read :* mite.

Page 222, line 1, *for :* never found, *read :* never been found.

Page 250, line 3, *for :* permite, *read :* permit.

Page 267, line 14, *for :* kitchenerii, *read :* kitcheneri.

Page 270, line 6, *for :* of fighting, *read :* for fighting.

Page 272, line 10 from bottom, *for :* then, *read :* than.

Page 278, line 10, *for :* a low, *read :* as low.

Page 279, line 4 from bottom, the comma should be after plants, not after sheep.

Page 279, line 9, *delete one* be.

Page 283, line 6, *for :* are, *read :* is.

Page 289. Under remarks column, note (2), *for :* was the, *read :* was then.

Page 305, line 1, *for :* an, *read :* and.

Page 306, lines 7 and 20, *for :* botton, *read :* bottom.

Page 309, line 19, *for :* fumigating of seeds, *read :* fumigating seeds.

Page 322, *for :* Criptoblabes, *read :* Cryptoblabes.

Table IX, column 1, *for :* 12 plants, *read :* 24 plants.

Tables XIV and XV. In these tables 204 1st picking and 48 2nd picking plants were examined, not 204 only as the headings indicate.

VOLUME I, PART I.

SECTION A.

INSECT AND RELATED PESTS INJURIOUS TO AGRICULTURAL CROPS.

SUB-SECTION I.

INSECT AND RELATED PESTS INJURIOUS TO THE COTTON PLANT.

I

THE PINK BOLLWORM

(*GELECHIA GOSSYPIELLA*, SAUNDERS.)

THE HISTORY AND ORIGIN

OF THE

PINK BOLLWORM.

There is little to record historically as regards the pink bollworm which, although it has been known to science for more than half a century, appears only to have come under the general notice of economic entomologists as one of the world's most important cotton pests within the last ten years or so. The insect first became known, so far as our present information tells us, in 1843, specimens being sent to England by a Dr. Barn from Broach in India. They were bred from American cotton grown from imported seed. The insects were described by Saunders in 1844 under the name of *Depressaria gossypiella*, Sndrs. (Tr. Ent. Soc. : Lond., 3, p. 284-5, 1844).

In a small work entitled «The Agricultural Pests of India» [1]*, by Surgeon General Edward Balfour, published in 1887, *Depressaria gossypiella* is recorded as a pest of cotton and it is mentioned also that the United States Agricultural Commissioner states that this pest sometimes destroys one fourth of the cotton crop of India. We find the pest noted several times under *Gossypium* in the Dictionary of the Economic Products of India [2] by George Watt, but no information of interest is given. One of the most interesting accounts, although only short, which has appeared is recorded in the Report of the Cawnpore Farm and other Experiment Stations in the United Provinces of India [3] for the year ending June 30th 1904. The note is by the Deputy Director who gives a description and valuable observations on what is undoubtedly *Gelechia gossypiella*, under the title of Pest N° III (not identified) — family Tineidæ.

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* For List of References, see end of Volume I, Part I.

In speaking of the economic importance of this pest the author states — p. 18 :

« If precautions are not taken the pest is capable of becoming so bad as to ruin the whole crop, more especially if double cropping is attempted ..... Speaking for the last two years at the Cawnpore Experimental Farm, N° III red larvæ [i. e. pink bollworm] have done the most damage; but at times the other two (*Earias insulana* and *Earias fabia*) have been equal in numbers; thus out of 80 bolls examined in April seventeen bolls contained the red larvæ and fifteen either that of *Earias fabia* or *Earias insulana;* the remaining bolls were empty but had been attacked. »

Maxwell-Lefroy writing on « An Outbreak of Cotton Pests in the Punjab 1905 » [4] says, p. 3 :—

« As a rule these three species are in fairly equal numbers in cotton in India; a peculiar feature of the present case is that the only species common was *Earias insulana*, the two others *Earias fabia* and *Gelechia gossypiella*, being absent or present only in normal and very small numbers. The damage to cotton was actually done by *Earias insulana* and we may neglect the other two species in discussing this outbreak. »

In Egypt we know that the severity of the attacks of *E. insulana* vary considerably and it is to be hoped that later this will also prove to be the case with the pink bollworm, *G. gossypiella*, as it appears to be in India.

Another interesting paper on this insect is that by Fullaway in Bulletin 18 of the Hawaii Agricultural Experiment Station [5]. From this we learn that it is the worst insect enemy of cotton in Hawaii where it is widely distributed. The pest is said to have been introduced from India. This species was recorded in Honolulu by Dr. R. C. L. Perkins as long ago as 1902 [6]. It is of interest to note that Fullaway also records *G. gossypiella* from a member of the *Malvaceæ* called milo (*Thespesia populnea*).

J. Vosscher (« Einige Feinde der Baumwollkulturen in Deutsch-Ostafrika, Amani 1904 ») published an interesting account of *G. gossypiella* in German East Africa where it causes considerable harm. He considers it may be indigenous to the country. Curiously enough it does not, according to this writer, attack the wild cotton (*Gossypium kirkii*) in that region, even if this plant was not more than an hour's walk distant from a cotton plantation heavily infected with the pest.

Dudgeon [7], writing in 1913 on the pink bollworm in Egypt, mentions it as occurring in West Africa (Southern Nigeria and Sierra Leone), but he gives no account of its habits there nor if it is supposed to be of recent origin. He infers that it is not a pest of very great importance, but then cotton cultivation is still in a very rudimentary state in West Africa and moreover only small areas are devoted to this crop.

As regards the original home of the pink bollworm we are still somewhat in the dark, although on the whole the available data would seem to point to its being in India. However, Durrant, a well-known authority on the Microlepidoptera, to which division the pink bollworm belongs, indicates in his paper « Notes on Tineina Bred from Cotton Bolls » [8] that the species is perhaps not of Indian origin, for he says :—

« Although originally described from Indian specimens it is by no means certain that *gossypiella* is truly an Indian species, for Dr. Barn's notes, as published by Saunders, indicate strongly that the insect was imported with American cotton which is prefered to the Indian species of *Gossypium.* »

Since *Gelechia gossypiella* has not been recorded from the New World at all it would seem to be highly improbable that it could have come from America to India in seed — in fact we may safely dismiss this suggestion, for surely if the pest was a member of the American and West Indian Islands fauna it would have made its presence evident in the cotton fields there. Even supposing it existed as a rarity — which the supposition that it was imported in American seed does not allow, since to be exported with small lots of seed it would of necessity have to be fairly numerous — it would hardly have escaped the keen eyes of the American economic entomologists for so many years. Again after showing that other specimens of *gossypiella* in the British Museum were bred from imported Egyptian cotton grown at Cawnpore and Lahore this author says :—

« It would therefore seem that both the Lahore and Cawnpore specimens were imported with Egyptian cotton » ..... The suggestion that *Gelechia gossypiella*, Sndrs., was imported into India with Egyptian cotton and thence distributed eastward receives some support since it has been bred in Egypt by Mr. F. C. Willcocks from larvæ collected in the Damanhour District, and in Zanzibar by Dr. W. M. Aders. »

There can be no doubt of course that *G. gossypiella* was associated with both American and Egyptian cotton grown from imported seed, but this is not astonishing as small plots of a fresh food plant often seem to be specially singled out for attack by the insects of the country in preference to the native varieties of the same food plant. In my opinion the pink bollworm was not imported to India from Egypt but, as will be shown later, the reverse was the case.

At present we do not know how nor when this species obtained a footing in British and German East Africa, nor in West Africa : probably it was introduced in cotton seed. The possibility must not be overlooked, however, that it may belong not only to the Indian region but also (although improbably) to parts of Africa where it fed naturally on wild cottons and other *Malvaceæ,* or on trees with oily seeds as it is said to do in India by Lefroy [9], and that subsequently it has turned its attention to cultivated areas of the cotton plant which are of recent origin, and where moreover, it would find favourable conditions for increase and thus come directly to the notice of growers and entomologists. However, supposing this were true it seems strange that it is not found in the Sudan, Abyssinia, nor in Somaliland where wild cottons [10] exist and nowadays cultivated cottons also.

On the other hand, *G. gossypiella* is a small moth with no great powers of flight, so one would not expect it to have a very wide natural geographical range. But the ease with which it might be transported from one country to another in seed is readily apparent when one considers that the insect may remain in the larval stage in a quiescent state for more than a year. Furthermore, unginned cotton used for the purpose of samples, bales of ginned cotton still containing some cotton seed, or again resting pink bollworms spun up in folds in the jute covering of the bales might all serve as the means of conveying this pest from place to place. Another manner in which the pink bollworm might conceivably be introduced into fresh territory is by steamers carrying, or that have recently carried, cargoes of infested cotton seed or raw cotton. The moths emerging in the holds would be able to make their escape when the hatches

were opened up at, say, some intermediate port, where by a lucky chance they might fly ashore and find foodplants of some kind available.

Again, merchandise of almost any sort might serve as the means of transport, supposing it had been lying in contact or close to a consignment of cotton seed in the same warehouse previous to shipment, at a time when the bollworms were leaving the seed to pupate.

It would appear probable that the pink bollworm has gained its present wide distribution by some such accidental means rather than by any migratory efforts of its own during the ages it has no doubt existed.

The habits of the pest lead one to suppose that it has long been associated with cotton and related plants. This fact taken together with the very marked æstivating powers of the species would seem to indicate that it belongs naturally to a country where not only have these food plants long existed, but also where the climatic conditions are characterized by long hot and rainless periods during which the food plant or plants, or at all events the necessary vegetative parts of them, would not be available. Such conditions as these are found in certain parts of India particularly, far more so than in any of the other countries now inhabited by *G. gossypiella*, and it seems highly probable that eventually India will be shown to be, beyond doubt, the original home of this pest, which is now rapidly becoming notorious owing to its unfortunately having been distributed to so many other cotton growing countries where in some cases, notably that of Egypt, it has caused enormous damage to the crop.

THE HISTORY AND ORIGIN
OF THE
PINK BOLLWORM IN EGYPT.

From the behaviour of the pink bollworm in Egypt during the past four years there can be little or no doubt that it has been introduced, and although we are not in a position to assign an exact date for this event, there is every reason to believe that it took place during the period 1903–1910. It has been stated already that in all probability India is

responsible for having given the pink bollworm to this country. The manner in which the transportation may well have taken place now seems clear owing to the work of the Ministry of Agriculture, one of whose Inspectors in examining bales of so-called ginned Indian-grown cotton imported to be spun at a spinning mill belonging to a private company on the outskirts of Alexandria, found live pink bollworms in seeds!* I have purposely specified *so-called* ginned cotton, since it appears that this process had been so badly carried out that there was a *very high* proportion of seed left in this particular consignment. The following table shows the amount of Indian cotton yearly imported into Egypt since 1903, the first year in which such consignments were received.

Table I.

QUANTITY OF INDIAN COTTON IMPORTED INTO EGYPT DURING THE PERIOD 1903 to 1913.

YEAR.	QUANTITY. in kilograms	YEAR.	QUANTITY. in kilograms
1903	20,510	1909	31,206
1904	25,827	1910	13,353
1905	9,150	1911	.....*
1906	81,240	1912	10,998
1907	162,000	1913	89,995
1908	21,460		

* Figure not available.

Although the pink bollworm may have been present in any one or all of these annual shipments, it is thought that had the pest really arrived as early as 1903 it would have increased to sufficient numbers for its presence to be revealed before 1910.

If we were in possession of sufficient data to enable us to say how long it would take for a species like *G. gossypiella* to spread all over Lower

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* I am indebted to Mr. G. Dudgeon, Consulting Agriculturist to the Ministry of Agriculture, for this information.

Egypt, it would not be difficult to assign a fairly close date for its introduction here. We have not, however, the necessary information; but we do know that in 1910 the pest was apparently rare although as regards distribution we are not in a position to say if it was confined to a few localities only, since the probability is that this was not the case at the time. In 1912, or the third season after its detection, the pink bollworm was by far the most common cotton pest in Lower Egypt. If it took three years for this pest to thus alter its status it probably took at least as long for it to increase from a comparatively few individuals to sufficient numbers for the species to be easily found. If we take the third year back from 1910, we arrive at 1907 and reference to Table I shows us that in this year twice as much cotton was imported as in 1906 in which year nearly double the amount of the previous three years was received. It is by no means improbable, in my opinion, that it was about this date, 1906-1907, that the pink bollworm gained a permanent footing in Egypt.

So far as I am aware, no seed for cultural purposes has been imported into Egypt from India within recent years, but possibly very small lots of Indian cotton seed were introduced early in the 19th century or much earlier still. It is of interest to note that in 1909 a scheme was set on foot to import Indian cotton seed in bulk into Egypt, for the use of crushing mills using this commodity to obtain oil. The very great danger which would have been run by the country of importing the pink bollworm if this suggestion had been followed was pointed out by the writer and the idea was abandoned. Unfortunately it was not realized at the time that badly ginned raw cotton was being shipped here from India, otherwise this dangerous practice would have been stopped then as it has been since, but too late to prevent the entry of *Gelechia gossypiella*.

About the year 1909 a considerable quantity of Caravonica cotton seed was introduced into Egypt from Queensland, Australia, but no sign of pink bollworm was found in the samples examined, moreover we do not know if this pest occurs in Australia; so far it has not been recorded from there. Thus we have no reason to suspect seed from this origin.

Furthermore, certain lots of this seed were fumigated with carbon bisulphide, but whether all were so treated I am unable to say, possibly not, since considerable opposition to this treatment was met with on the part of some of the consignees who declared that it destroyed the germination of the seed. As a matter of fact, however, fumigation does not affect seed in this way in the slightest degree. Mr. Andres thinks that it is possible that certain of the consignments of Caravonica seed may have been imported from German East Africa. Unfortunately we are at present quite unable to verify this, but if it occurred it is of very great importance, as we know that this part of Africa is infected with pink bollworm which would in all probability infest Caravonica seed very badly — as is the case in Hawaii — because the plant is grown as a perennial. Failing other evidence it is safe for the present to regard India as the first source of the pest as far as Egypt is concerned.

The year 1910 is of great importance, marking, as it were, the first public appearance of the pink bollworm. One larva was found by the writer in a parcel of 156 green bolls received from Damanhour on November 30th 1910. A single *Gelechia* larva only was found; fifty of the bolls were sound and 106 attacked by *Earias insulana*. On December the 10th 1910, in a lot of 245 green bolls sent from Mansourah, a single pink bollworm was found in a seed : 127 bolls were infested with *Earias insulana* larvæ and 115 were sound. It would thus seem that the pest was not very numerous at this time. Parcels of green bolls had been received from other localities in Dakahlia, Menoufia, Kalubia, Fayoum and Minia during November 1910, but unfortunately the bolls had not been opened previous to the discovery of the pink bollworm, external signs being sufficient evidence to show if the boll had been injured by *E. insulana*, the object of the examination then being made. At the same time, however, it is somewhat significant that none of these larvæ were noted free amongst the bolls as was the case with the Damanhour larva. But it would be quite unsafe to assume from this that the bolls were free from *Gelechia* larvæ, since the proportion of larvæ which voluntarily leave the green bolls so late in the year is very small.

From the two larvæ obtained in 1910 one moth was bred out May 1st 1911 and this specimen was in the autumn definitely identified as the pink bollworm moth, *Gelechia gossypiella*, Sndrs., by Mr. Hartley Durrant of the British Natural History Museum. My sincere thanks are due to Mr. Durrant for this and many other identifications.

In the autumn of 1910, the larvæ of this species were received also by Mr. Andres from Cherbine, a little way north of Mansourah. Mr. Andres requiring more specimens sent an assistant to search for them. The latter first visited a field in the neighbourhood of Kafr-el-Dawar and there found the pink bollworm to be present, but only in very small numbers. From these larvæ moths were obtained in June 1910 and were forwarded by Mr. Andres to Professor Rebel of Vienna who determined them as *Gelechia gossypiella*, Sndrs. Mr. Andres was the first to place on record the occurrence of this species in Egypt in the «Bulletin de la Société Entomologique d'Égypte», 1911, 3e fascicule, Juillet-Septembre, and also the 4e fascicule, Octobre-Décembre, 1911.

The fact that the insect was received for the first time from widely separated localities indicates that it was then already well established in Egypt, since it can hardly be suggested that they were the points of its introduction, but places to which it had spread from the original focus of infection. With regard to the latter, suspicion of course rests on the spinning mill at Alexandria* which is situated within easy distance of cotton fields — and furthermore, Mr. Andres informs me that cotton plants growing in the garden of the director never produced any fibre much to the latter's surprise, the reason being that all the bolls were so heavily infested with bollworm that they did not open. Unfortunately we do not know which species was concerned. Both in 1912, the first year for which we have at all detailed records of the pink bollworm, and in 1913 it appeared that

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* It appears now that the first few annual shipments of imported Indian cotton were sent to a spinning mill in the suburbs of Cairo and not Alexandria. However, what evidence there is would appear to point to the later consignments which *were* sent to the Alexandria mill as being more probably responsible for the introduction of *G. gossypiella* into Egypt.

Behera Province was the most heavily infested especially round Damanhour and Kafr-el-Dawar. This would seem to lend support to the supposition that it was in Behera that the pest was first introduced and established itself. It is worthy of remark also that there are several large ginning factories situated at Damanhour and others — the largest in Egypt — at Kafr-el-Zayat on the borders of Behera Province. Thus much of the infected cotton would come to these factories and later the seed would be distributed all over the country. It is highly probable also that the cotton in the neighbourhood surrounding these establishments would be likely to be heavily attacked, the factories acting as centres for the collection of pink bollworm from a very wide area indeed. A propos of this, it is perhaps of interest to note that in 1912 bolls received from a number of cotton fields situated close to Damanhour and Kafr-el-Zayat were very badly infested with the pink bollworm, far more so than bolls received from any other part of the Behera, Gharbia or other parts of Egypt.

It will be readily understood that supposing the pink bollworm had been recognized as an introduced pest at this date it would not have been possible to eradicate it from Egypt by the employment of such methods as the following: — Prohibiting the employment of tagawi seed originating from the infested localities, only a few of which were known out of possibly hundreds; prohibition of cotton growing in certain areas; destruction of all the cotton sticks and late bolls in the then known infested regions together with the seed from these crops. Even if any or all of these methods had been practicable and put into force, they would have been quite futile, since the pest had already obtained too strong a grip on the country and was in all probability present in *very small* numbers at any number of points within the radius whose length was the distance between any two of the places already mentioned, viz. : Mansourah—Damanhour, Damanhour—Kafr-el-Dawar and Mansourah—Cherbine, and perhaps it was even still more widely distributed. The fault of the introduction of this pest was due to the lax laws or absence of laws in Egypt at the time for preventing the introduction of foreign insect pests and plant diseases on plants and parts of plants, in seed, etc. It must not be thought,

however, that no one realized the risks being run; the Agricultural Society was fully alive to them, but it was not possible to do anything at this period and things were allowed to slide until a severe lesson has taught Egypt the necessity of protecting herself by legislation from further calamities in the form of introduced pests.

It must be admitted it was not realized at the time of the discovery that *gossypiella* was a recently introduced insect, but it was considered as a species indigenous, or practically speaking so, to Egypt, but very rare. It is perhaps of interest to note here that curiously enough during the summer of 1910, when the writer was in England, that Mr. Hartley Durrant of the British Museum commented on the fact that *G. gossypiella* had not been recorded from Egypt and expressed the opinion that careful search would probably reveal its presence there as a rare insect feeding occasionally on cotton, and furthermore he considered it quite probable that India might have received the pest from Egypt and not vice-versa. Unfortunately for Egypt, Mr. Durrant's views on the presence of the insect proved only too true, for it was found in November of that year. Equally unfortunately also Mr. Durrant's opinion about the origin of the pink bollworm does not appear to be borne out by the facts of the case and it seems that Egypt has received the pest from India and thus has an introduced insect with all its attendant dangers to contend with. As all know now, this species has proved to be of the first importance and so far the extent of its injuries have, generally speaking, increased each year. However, on the whole, one would expect this behaviour from a new pest finding exceptionally favourable food and climatic conditions and possibly freed from natural enemies to the attacks of which it may have been subjected to in its native country.

Andres [10a] apparently came to the conclusion that *gossypiella* had been a resident of Egypt for some considerable time, since he says :—

«Il y a lieu de supposer qu'en Égypte leurs dommages ne sont pas moins importants et qu'ils ont été confondus avec ceux causés par l'*Earias insulana*.»

We must infer also that Dudgeon was of the same opinion as late as

1913, for he says in the opening paragraph of his paper «The Pink Bollworm»[11] :—

«The occurrence of the Pink Boll Worm in Egypt appears to have been overlooked by writers upon the subject of cotton pests in Egypt, previous to 1911, although specimens have been found commonly in damaged cotton cells throughout the country for many years.»

And again — page 2 — à propos of the lack of a complete account of the life history of the pest in Egypt, he says :—

«This deficiency in Egypt is perhaps accounted for by the fact that the damage done is frequently very small, and where, as in Egypt and India, the insect occurs together with the more conspicuous *Earias insulana*, the destruction of the bolls is frequently entirely attributed to the latter insect.»

It was pointed out in a letter written by the writer to Mr. Dudgeon that most probably his first statement had been based on a misconception and that the specimens referred to as having been found in damaged bolls previous to 1910 were more likely to be the larvæ of a small moth *Pyroderces simplex*, Wlsm., a debris feeding species. Mr. Dudgeon agreed as to the probability of this being the correct explanation of the occurrence of pink larvæ in cotton seed previous to 1910 or 1911.

In the year 1911 we have no records of *G. gossypiella* and whatever injuries it caused appear to have passed unnoticed for the crop was considered satisfactory. On the Society's Farm at Bahtim there was some loss from bollworm but whether the two species *Gelechia* and *Earias* were involved is not known, the writer being away from Egypt at the time.

In September of 1912, Mr. Andres, Assistant Entomologist, who was carrying on the work of the entomological laboratory in the absence of the writer from Egypt owing to illness, was working with the parasites of the ordinary bollworm *Earias insulana* and, requiring numbers of the larvæ of this species, sent out a request to the district inspectors of the Society for unripe bolls from various parts of Lower Egypt. In examining these bolls, Mr. Andres was somewhat astonished to find the pink bollworm quite common. This discovery led him at once to make a more detailed

examination of bolls from many localities, with the result that the species was found to be, not only widely distributed, but numerous as well. Mr. Andres then realized the importance of and grave menace for the future of the Egyptian cotton crop to be apprehended from the pink bollworm. A short pamphlet in Arabic was prepared and issued by this Society giving the details of the boll examination, a short account of what was then known about the life-history of the insect and an outline of the measures which might be adopted for its control.

Further work in November revealed the fact that the whole of the delta of Lower Egypt was infested and that the pest also occurred in parts of Upper Egypt. Moreover, by the end of the season it was evident as shown by Table V that *G. gossypiella* was present in much greater numbers than the ordinary bollworm *E. insulana* in the case of Behera, Dakahlia and Kalubia Provinces and the neighbourhood of Cairo. But in Gharbia, Sharkia and Menoufia Provinces, *Earias* appears to have had the ascendency as regards numbers. However, taking Lower Egypt as a whole, the losses from bollworm attack may be said to have been, practically speaking, about equally divided between the two species.

In Upper Egypt conditions were reversed and *Earias* appears to have completely outnumbered the pink bollworm and here practically the whole of the damage — which, according to the crop reports of the Ministry of Agriculture, was slight — may be attributed to the work of the former species.

In 1913, the pink bollworm may be said to have fully showed its hand and it was realized by all that a very serious problem had arisen in the cultivation of cotton in Egypt. The losses this year were very much more severe than in 1912 and probably few growers failed to see, and many to feel as regards their pockets, the work of the pink pest in their fields. This year we find many references to the insect in the local papers both Egyptian and European. The United States of America also began to be uneasy owing to the possibility of the pest being introduced in the Southern cotton growing States, through commerce in cotton seed, raw cotton, etc. with Egypt.

The Ministry of Agriculture now took the matter in hand and through its efforts the already existing law relating to the control of the ordinary bollworm (*Earias insulana*) was remodelled so as to include and be effective against the new pink bollworm. If this law was properly carried out, which it has not been up to the present, it should do much to keep both these pests within bounds and prevent them from causing great damage. However, to make the law quite effective it will be necessary to take measures to destroy the pink bollworm in the seed as well.

It is perhaps worthy of note that the early prospects of the cotton crop in 1913 were exceedingly good and the Ministry of Agriculture estimated a brumper crop of somewhere in the neighbourhood of seven and three quarters to eight million kantars. When, however, the pickings came to hand there was a general outcry against the official estimate as being far too high and likely to prejudice the price to the growers' disadvantage. Deputations were even sent from the Provinces to ask that the figures might be reconsidered. But, as a matter of fact the final figure for this year's crop was 7,663,800 kantars. This is considered a big crop for Egypt and it was some one hundred and fifty thousand kantars more than was produced in 1912 on an increase in area of only 1,200 feddans of land over that of 1912. In the latter year the pink bollworm was hardly heard of and in 1913 it was a general topic of conversation, and yet the reported severity of the attack of this pest appears to be in no way reflected in the crop figures for the two years. One might thus be led to think that the accounts of the ravages of the pink bollworm had been greatly and generally exaggerated by growers for according to popular estimate in the autumn, the crop of 1913 was to have been well under seven million kantars.

However, the difference between the two figures does not, in the opinion of the writer, really show the actual destruction wrought by the destructive *Gelechia* larvæ, since this season (1913), excepting for insect pests, was particularly favourable for the cotton crop and the plants produced and ripened sufficient bolls to produce about ten million kantars of seed-cotton, but thanks to the work of the pink bollworm an enormous

number of the ripe bolls were, practically speaking, only shells containing little or no pickable fibre.

This year we find a very marked difference prevailing in the proportion between *G. gossypiella* and *Earias insulana*. Reference to Table V shows that the latter species was comparatively scarce both in Upper and Lower Egypt, being altogether outnumbered by the pink bollworm and, practically speaking, it was this species alone which was responsible for the whole of the bollworm injury to the cotton crop.

In 1913, since it was impossible to compel people to destroy the bolls remaining on the cotton sticks after the last picking, as the new law did not come into operation until 1914, nor was it practicable to treat the infested seed before sowing, the opinion was freely expressed that the pest would do equal if not greater damage to the 1914 crop.

Unfortunately this has proved to be the case. The pink bollworm appeared in July and from then onwards increased until not only was the first picking injured to a greater extent than 1913, but in some localities there was practically no second picking at all and the third picking was destroyed so far as marketable fibre was concerned. The quality of the second picking was also very inferior. In spite, however, of the very serious attack, the first picking in certain localities, situated chiefly in the Behera Province, were considered satisfactory. We have been informed on good authority that, generally speaking, the pink bollworm attack in the Behera had been decidedly less severe than in the previous year. If true, this is indeed a hopeful sign as it would appear to indicate that the pest reached, as it were, its high tide mark last year and is now receeding. Certainly one would expect this to first show signs of occurring in the North, more especially in Behera Province where it seems probable that the pink bollworm first gained a strong hold on the country. As to the reasons for this decrease in the injuriousness of the species — if it proves to be a reality — we can only conjecture that it is due to natural enemies and perhaps even more so to a greater susceptibility to disease.

However, it does not by any means seem certain that the pink bollworm attack was really less severe in Behera Province in 1914 than in 1913.

As different reports were obtained on this question from different sources: the writer had a special inquiry made in this part of the country by a reliable observer, among the proprietors of large estates, their employees and also amongst the small cultivators and fellaheen. This census showed that along a line from Damanhour north-west to Alexandria there were eleven localities where the attack was said to have been less and eight in which it was more serious than in 1913. Along a line from Damanhour south-east to Taufikia and east to Shibrakhit it was stated to have been worse in 29 localities and better in only one. From Shibrakhit northwards to Atfeh and then south *via* Zurkum and Sanhour to Damanhour the attacks of the pest were more injurious in 1914 in 12 localities and better in eight than in 1913. The total gives 49 localities in which the attack was more severe and 20 in which it was less so in 1914 than 1913.

Speaking generally, the damage in the north of Gharbia and Dakahlia has been as bad or rather worse than in 1913. As regards the Provinces of Menoufia, Sharkia, Kalubia and Gizeh, there can be little doubt that the attack has been most decidedly heavier and it is this part of Egypt which is chiefly responsible perhaps for the poor crop of 1914. It must be remembered also that not only was the crop poor as regards quantity but also quality. The poor demand for and price offered for cotton consequent on the war led, so we are informed, to many small cultivators leaving the first picking on the plants some time after it was quite ready to pick; the result was that the first and part of the very inferior badly damaged fibre of the second picking was taken together thus lowering the value of the whole very considerably. How general this practice was, we are unable to say, but it is to be hoped that it was of rare occurrence, since it is most prejudicial to the quality of the crop.

The ordinary bollworm has again been scarce compared with *Gelechia* both in Lower and Upper Egypt. This was indeed a fortunate occurrence, for had *Earias* been as numerous in 1913 and 1914 as it was in 1905 or even 1909 the probability is that cotton crop would have been almost ruined.

PROSPECTS.

It will have been gathered from the preceeding pages that the rise to importance and spread of the pink bollworm in Egypt has been very rapid. In 1910 it was apparently a rarity, being known to occur in very small numbers in three localities only; in 1913 or three years later it was the most common and also the most injurious pest to be found in the cotton fields. The reason for this speedy rise to notoriety is not difficult to understand when we consider the following factors which bear on the question :—

Firstly, it seems that there can be no doubt that *G. gossypiella* has been introduced recently into this country where as regards food supply, it found ideal conditions, since during the period of this insect's greatest activity (July-October) its food-plant — cotton — extends in an almost unbroken series of fields throughout Lower Egypt (The Delta) and then south of Cairo along the comparatively narrow cultivated strip forming the valley of the Nile well into Upper Egypt. Thus the small and delicate moths have not to expose themselves to the many dangers of destruction to which they would be liable if they had to make long journeys in search of food plants in open country, but their food lies as it were at their very door. Furthermore, at this time the plants are bolling rapidly and a plentiful supply of bolls is advantageous for the newly hatched larvæ or bollworms, which, if they have to wander about on the plant for a long period before finding a boll or square (flower bud) to bore into, are much more likely to fall victims to predaceous insects or other causes. The system of cropping or rotation followed in Egypt is also more favourable than otherwise to the pest.

Again, the climate of Egypt seems particularly well suited to the needs of the pink bollworm, since during the greater part of its inactive or resting period it is not subjected to particularly trying temperatures of long duration, except perhaps as regards parts of Upper Egypt where the prevailing high temperatures may possibly exercise a considerable control

effect on the increase of this pest. In Lower Egypt also larvæ resting in bolls lying on the ground, exposed to the full glare of the sun, will perish in great numbers, being actually killed by the heat. Larvæ so situated are not likely to survive after May.

During its active season this insect finds, generally speaking, a high average temperature combined with a considerable degree of humidity which no doubt ensues rapid development and a minimum mortality during the egg and newly hatched larva stages. Generally speaking, high temperatures and dryness would tend to increase the death rate for these two stages.

The habit this insect has of spending long periods in a quiescent state as a larva inside the seeds of the cotton plant considerably facilitates its dispersal. Seeing that the whole cotton crop of Egypt is sent to a comparatively few centres to be ginned and from the factories the seed is again distributed to all parts of the country for sowing purposes, it will be readily understood that the pest stands a very good chance of being quickly distributed in this manner alone throughout the country. Furthermore the spread of the species is aided by the unbroken sequence of cotton fields in all directions, from north to south and east to west, the absence of any natural barriers in the nature of mountains, forests, uncultivated belts, etc., and lastly the prevailing wind being from the north to the north-west is favourable, since it tends to help or direct the flight of the moths southwards.

It would seem then that through the agency of man the pink bollworm has been able to invade new territory where, as regards food and climatic conditions, there is nothing to check its increase.

Thus for the moment setting aside the possibilities of artificial control, which most fortunately appear to be very great, it might well be thought that the prospects for this pest still continuing and perhaps further increasing its powers of injury were very favourable. Happily however, there is also the factor of natural control by parasitic and predaceous enemies and other agencies to be considered. At present we can say but little more than that a number of parasitic insects and both predaceous

insects and mites are known, since before their economy and just value can be defined a much more complete investigation will have to be made, necessitating more time than it has so far been possible to give to this — a most important section of the pink bollworm problem. It is satisfactory to know that natural enemies were undoubtedly more numerous in 1913 than in 1912 on the Society's Farm at Bahtim, near Cairo, but at the same time the pink bollworm was also more numerous. In 1914, the parasites or rather certain of them seemed on the whole to be less abundant than the previous year, whilst *G. gossypiella* was again more injurious. It would, however, be a great mistake to draw hasty conclusions, based on observation in a single locality, as to the future status of and benefits to be expected from the natural enemies of the pink bollworm.

We are still in the dark as to whether this pest brought any of its particular natural enemies with it from the land of its introduction or if those which attack it here are all native to Egypt and have adopted the pink bollworm as a new host. That this is so is the case of one species — *Pimpla roborator*, Schmed. seems certain. If the pest has really left its natural enemies behind in its country of origin — India — it will of course be under a great advantage — an advantage which would partly explain the great increase and powers of injury in this country.

In dealing with parasites it must not be forgotten that there are parasites of parasites giving rise to what is known as hyperparasitism. In this way the useful work of parasites of injurious insects may be much impaired owing to the fact that their numbers may be much reduced by the attack of their hyperparasites. It thus becomes a matter of great importance to work out the exact nature and habits of the many different members of the order Hymenoptera which can be bred from cotton bolls infested with the two species of bollworms. At present it must be admitted that our knowledge of the parasites of *G. gossypiella*, both in this and foreign countries, is decidedly rudimentary and so we are not exactly in a position to judge the present or future effect natural enemies will have on the increase of the pink bollworm. Whether if matters were allowed to take their natural course the parasites would eventually increase to

such an extent as to effectively control the pest seems to be rather problematical, since we already know that in India — the probable origin of this species — that it often causes very heavy losses to cotton growers. In India the pest should be placed most unfavourably as regards natural enemies which are generally considered to be most numerous and most effective in the natural home of the host insect. However, it may be hoped that in a few years the control effect of the parasites and disease will be much greater than it is to-day, but at the same time it is most probable that artificial methods of control will always be necessary in Egypt if the pest is to be prevented from causing serious damage periodically.

Another point of sufficient interest to be examined, since it appears that it might to some extent act as a brake on the amount of injury the pink bollworm is capable of causing, is the question of the activity period of this species. If the emergence curve on Plate II is consulted it will be observed that *G. gossypiella* has a long but well defined summer and autumn period of activity as regards the emergence of moths from the resting larvæ of the previous year. Commencing at the end of June it continues to the end of October, with the maximum transformation to the pupal stage and subsequent issue of moths occurring about September.

If this course is substantially the same from year to year, the pest would appear to have only a limited period in which to increase and moreover by the time it had reached sufficient numbers to become really serious, the first and by far the most important picking should be in normal years and for normal sown crops in the south and middle Delta but perhaps not in the north, to a great extent safe from a heavy attack both as regards the number of bolls to be pierced and the effect of invasion by bollworm on those bolls which are attacked, since the nearer the boll is to maturity the less will be the injury caused by the larva to the fibre.

Unfortunately we are not able to state definitely that this will be the case, nor that the prospects for the first picking escaping a much increased

percentage of injury in future years are certain, because we do not know yet if the main attack of the pink bollworm from the middle of August to the end of October is caused by the offspring of the moths — some of which, by the way, we think may be only single brooded — emerging during July, August and September or chiefly to the progressive increase of the very small numbers of moths issuing from April to July.

We are inclined to think that the late July and the August and September moths arising from the previous year's larvæ are mainly responsible, since if the moths emerging in early spring and subsequently to the end of June, were of equal importance, one would expect to find the pink bollworm more numerous in the cotton fields in June, July and August than actually appears to be the case, and furthermore that the first picking would be more heavily damaged than it is.

On the Society's Farm at Bahtim, near Cairo, the bollworm attack this year — 1914 — was very severe indeed, yet at the end of June an examination of flowers and «squares» showed that only 0.2 to 0.4 per cent were infested with *Gelechia* larvæ. By the third week in July, about 6 per cent of the bolls were attacked, and by August 17th, this had increased to 11 per cent. At the time of the first picking about 56 per cent of the ripe bolls showed signs of injury by pink bollworm, but only about 27 per cent of these had been at all seriously injured and a still lower percentage (18.7 per cent) failed to give any fibre. The second picking suffered out of all proportion to the first at least 90 per cent of the ripe bolls showing signs of attack, and a very high percentage (45 per cent) of bolls gave no cotton at all or, if they did, only cotton of a very low grade indeed.

Comparing the 1913 with the 1914 crop (see Tables XIV and XVII) it would seem that the injury to the first picking was more severe in 1914 on the Society's Farm. As regards the second picking the percentage of attacked bolls was much about the same, but the actual damage done to the bolls was perhaps greater owing to the slightly larger average number of larvæ infesting each.

From these observations it seems to us that so long as the control

exercised by natural enemies and artificial methods employed remain more or less ineffective the damage to the first picking may increase in the future, but not, it is hoped, to an alarming extent, since whilst the pink bollworm is still on the increase the number of larvæ entering the resting stage at the end of the cotton season is likely to be larger and we may suppose that those which survive and give rise to moths in the following July and August will be in proportion more numerous also. This increase will be reflected again in the larger number of first picking bolls to be invaded giving rise to what will appear to be an earlier attack owing to the greater ease with which the pest can be found in July and August.

We have considered so far only the work of the natural enemies, but there are the artificial methods, which may be employed to check the pest, to be examined. Fortunately the prospects in this direction are decidedly very hopeful, for although no one who has studied the pest supposes that it will ever be exterminated in Egypt, they are, I think, unanimous in believing that if the resting larval stage can be destroyed in large numbers enormous benefits will result reducing the loss from both the pink bollworm and also the ordinary bollworm (*E. insulana*) to a minimum.

So far as we know at present the pink bollworm feeds only on cotton, bamia, teel or hemp and the ornamental hollyhock (*Althaea sp.*) in this country. The long period from the end of one cotton season to that period in the succeeding one when the plants are bolling is passed by the pest as a resting larva or caterpillar in the seeds of the known food plants. Thus if we destroy all damaged bolls and seed capsules of these plants in the autumn we destroy countless numbers of the resting pink bollworms. If this measure is supplemented by the treatment of the cotton seed by heat or fumigation to destroy the larvæ which may be present in considerable numbers, and furthermore, none of the food plants are allowed to grow during the winter it is hoped that the numbers of the pink bollworm will be so reduced that the increase of those which survive in other situations will not be sufficient to seriously harm the crop.

A law has already been passed making it compulsory for all growers of cotton to remove and burn all the bolls remaining on the plants within a specified time after the last picking and in any case before the plants are pulled up and removed from the field. At present this law does not deal with the hemp (*H. cannabinus*) and the bamia (*H. esculentus*) both of which may be attacked — in some cases severely so — by the pink bollworm. One cannot of course compare the area of these two plants grown with that of cotton, since it is infinitesimal in comparison, but it is not the quantity grown which constitutes a danger so much as the chance of a few plants being forgotten in odd corners here, there and everywhere, or perhaps stored for months in ezbehs and other places with all the seed capsules left on the stems. This law does, however, prohibit the growth of these two food plants of *G. gossypiella* during the winter months, but unfortunately it is by no means always carried out to the letter.

The question of the treatment of seed intended for sowing still remains to be dealt with, but all concerned show a desire to take this matter in hand and no doubt the large ginning companies will be quite prepared, if further researches show it to be essential or at least of considerable importance, to install the necessary machinery for destroying the pink bollworm in cotton seed.

As regards the law compelling the destruction of the dead and useless bolls, it will probably require one or two seasons before the measure works smoothly as there is likely to be opposition or perhaps passive resistence to it in many cases, chiefly owing to ignorance. The majority of the large farmers are fully alive to the importance and utility of the new law. Another, but we will hope quite temporary, reason which has greatly added to the difficulty of carrying out the law this past season is the scarcity of money in Egypt owing to the war, thus the operation of picking off bolls costing about 20-50 piastres per feddan* is a serious matter to cultivators with from 50 to 500 feddans or more of

* A feddan is about 1 acre in area.

cotton, many of whom found it impossible under the circumstances to effectively carry out this work but not from any want of willingness to do so or want of comprehension of the value of what after all is, and will come to be regarded as such, a necessary part of the cultivation of cotton.

There is another important matter to be considered, viz., the possibility of the beneficial results to be expected from the destruction of all the infested bolls after the last picking of fibre has been taken, being seriously reduced by those bolls harbouring the pest which will be knocked off at the time of picking and again when all the remaining bolls or the plants themselves are removed from the fields at the end of the season. Some of the fallen bolls will remain on the surface, others will be ploughed into the soil, their disposal depending largely on the crop following cotton. Again the possibility of the pest passing the resting stage in situations other than in the bolls and seed must not be overlooked. These questions will be discussed in another section of this report, and it will suffice to mention them here and further to add that, although we have not yet the complete answers considerable progress has been made in this direction.

As regards the immediate future — the 1915 cotton crop — it will be as well perhaps not to be optimistic. The past season has been an exceedingly bad one for the pink bollworm, in fact the worst on record — taking the country as a whole. Thus in the absence of definite knowledge as regards the exact status of the parasites at the present time, whether more or less numerous than last year, together with the fact that the provisions of the Decree making compulsory the destruction of the bolls at the end of the season have not been carried out anything like as effectively as will be the case in the future, it does not appear to be at all improbable that the number of resting pink bollworms left in bolls alone will be very large. In addition there is the possible danger to be apprehended from the larvæ in the seed capsules of teel and bamia left about in odd corners. Furthermore, besides the possibility of the larvæ successfully surviving in the fallen bolls and in other situations, there are other issues which next year may tend to mask the benefit which

we hope will accrue from any destruction of bolls that has already taken place or will subsequently be accomplished. For instance the treatment of the infested cotton seed employed for sowing the new crop will be impossible this year. Again, as the result of the war, it is not unlikely that much greater stocks of cotton seed will remain in Egypt at various centres, and a great quantity of this seed is likely to be very heavily infested with pink bollworm, the result of the severe attack of this pest in 1914. Yet again, in addition to the low grade cotton sometimes kept by ginning establishments for trying and cleaning the gins before working on the new crop, there is the possibility of some growers holding over stocks of unginned cotton this year on account of the low prices prevailing at the moment.

When the activity period of the pest commences in June or July of next year, there seem to be good reasons for supposing that large numbers of moths from all these different sources will find their way into the cotton fields. These moths will operate on an area of cotton one third or about 585,090 feddans less than in 1914 in accordance with the terms of the Decree (Décret du 30 Octobre 1914 réduisant au tiers au lieu du quart la superficie à cultiver en coton en 1915) prohibiting the cultivation of this crop on more than one third of the land of any proprietor, in order not to still further congest an already overstocked market.

Supposing that the numbers of moths issuing during the period July-October is only about the same as was the case in 1914, they have an area of food plants 1/3 less in extent to work upon, thus the inference is that they will be more concentrated and will cause as much damage to the remaining 2/3 as they would have caused to the whole normal area of 1,723,000 feddans of cotton in an ordinary year. On the other hand, the parasitic enemies will find a more concentrated supply of hosts, but the benefits to be derived from this source are somewhat of an unknown quantity, and on the whole it will not be surprising if the attack of the pink bollworm in 1915 is as severe or even much worse than it was in 1914. However, to look at the bright side of things : firstly, we may hope that the indications of a less severe attack in Behera

Province during the past season will not only continue and increase there, but also manifest themselves in other Provinces further to the south or east. Secondly, when conditions are again normal and the boll destruction law is carried out at the right time and in a really effective manner, and all the cotton seed is treated by heat or fumigation, and perhaps other methods of control are adopted also; to say nothing of the greater help to be hoped for from an increase of the natural enemies, the outlook is most decidedly promising, and the pink bollworm should cease to be a menace to the prosperity of Egypt, which at the present time it most certainly is.

Finally, another and perhaps the last nail will be driven into the coffin of the pink bollworm, in fact both bollworms, the day when really early maturing varieties of cotton suitable for growth in the different cotton zones of this country are obtained.

Note I*.

Since this section of the report was written, we learn that the Ministry of Agriculture are enforcing the law for the destruction of the old cotton bolls and are actually burning or causing to be burnt all cotton sticks which still bear bolls, whether these are in the fields in heaps or stored away on the tops of houses. If this is being done at all thoroughly and the inhabitants do not largely evade the law by passing the word on and pulling off all bolls on the outside of the heaps of sticks or else by hiding the latter under maize stalks, etc., it alters the situation considerably, rendering the outlook for 1915 most decidedly better. But even under these altered circumstances, because of the reasons already spoken of, neither surprise nor disappointment should be expressed if the pink bollworm causes serious harm to the next crop, nor should it be regarded at once as demonstrating the failure of the law making the destruction of bolls compulsory to accomplish its purpose; thus it should not be condemned as useless for to do so would be a great mistake, since under no circumstances can it be described as useless, adversely affecting as it does three of the principal cotton pests, viz.: — the pink bollworm (*G. gossypiella*), the ordinary bollworm (*E. insulana*) and the cotton seed bug (*Oxycarenus hyalinipennis*).

Note II*.

It now appears that the intention of the Ministry of Agriculture to enforce the law relating to the destruction of cotton bolls before the plants are pulled up — by actually

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* These two notes were added during the winter 1914-1915.

destroying by burning all cotton sticks found with numerous damaged bolls on them — has had to be abandoned owing to the great and in some cases fierce opposition on the part of the owners of the sticks. This opposition is not to be wondered at, considering the scarcity of and high price of coal in Egypt owing to the war, and consequently the greatly enhanced value of cotton sticks as fuel. It is, however, of great interest to note — as pointed out to the writer by Mr. Greiss, Lecturer in Agriculture at the Agricultural School, Gizeh — that it is this increased value of cotton sticks as fuel which may in some cases perhaps, lead to beneficial results because additional stocks of cotton sticks are being bought up by owners of land who have to lift water for irrigation purposes, for raising steam in the pumping engines in place of coal. It is thus not improbable that a very much greater proportion than usual of the previous years cotton sticks will have been consumed before the activity or danger period of the pink bollworm commences towards the end of June.

DISTRIBUTION OF THE PINK BOLLWORM.

Geographical.

According to Durrant[12] the pink bollworm has the following habitat :—

Africa : Egypt, British East Africa, German East Africa.

Asia : India, Ceylon, Burma, Straits Settlements, Japan, Philippine Islands.

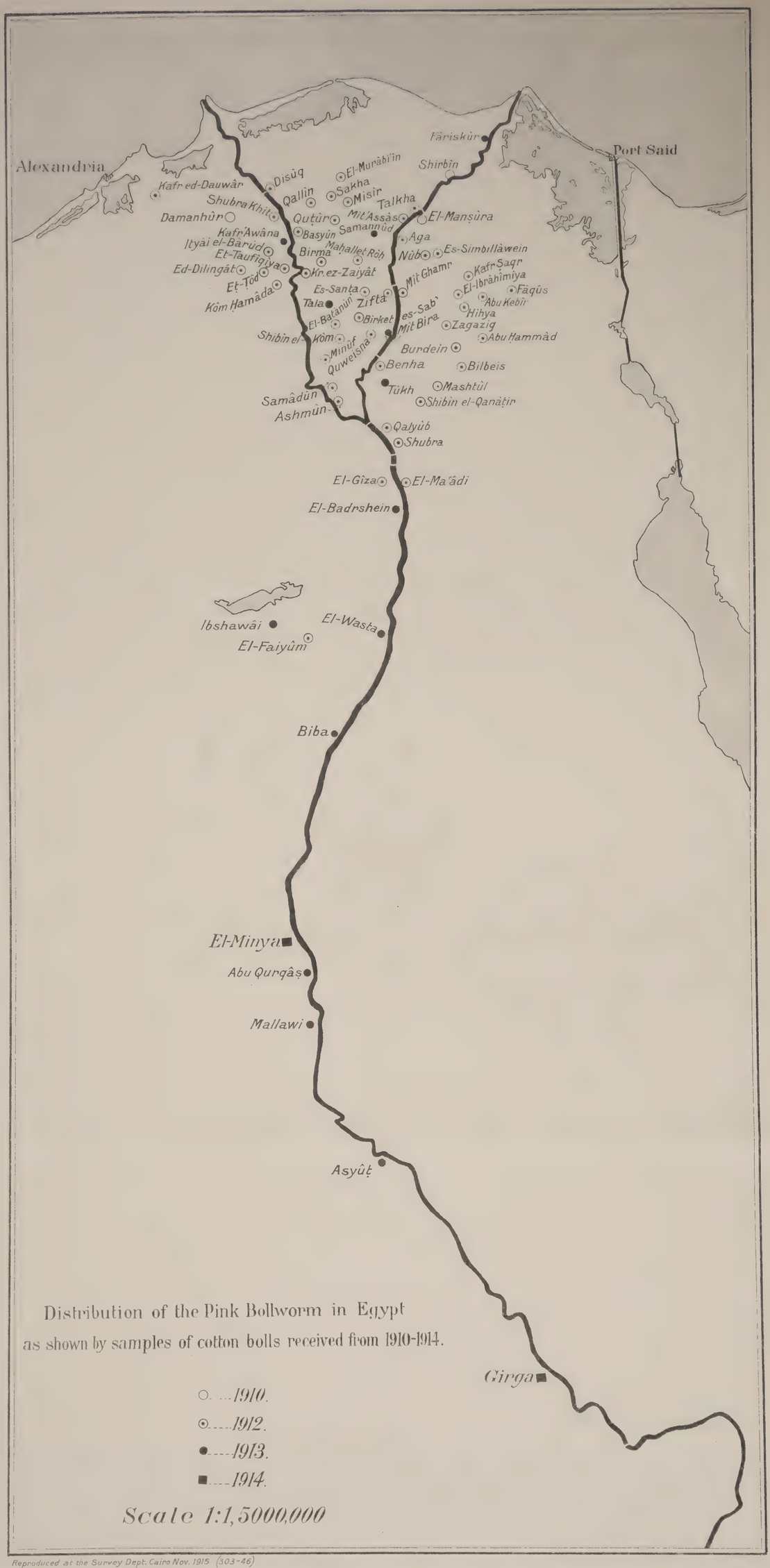
Hawaiia.

Dudgeon[13] records it from West Africa — Sierra Leone and Southern Nigeria.

Fig. 1. — ■ = Geographical distribution of the Pink Bollworm.

Distribution in Egypt.

In 1910, Damanhour, in Behera Province, and Cherbine and Mansourah, in Dakahlia Province, were known to be infected areas. In 1912,



Distribution of the Pink Bollworm in Egypt
as shown by samples of cotton bolls received from 1910-1914.

○ ...1910.
⊙ ....1912.
● ....1913.
■ ....1914.

Scale 1:1,5000,000

Reproduced at the Survey Dept. Cairo Nov. 1915 (303-46)

the pest was shown to be present throughout Lower Egypt as shown by the accompanying map, Plate I.

In Upper Egypt the pink bollworm was found in samples from Gizeh and Fayoum, in the Oasis of Fayoum. Samples from Ezbet Abaza, Mansourah, Fakusah and Tala, all in Minia Province, gave negative results as regards *G. gossypiella*. From a farm at Assiut, in Assiut Province, 400 bolls were examined but no pink bollworms were found.

In 1913, several additional localities were recorded in Lower Egypt. In Upper Egypt, the pest was received from Oseem and Badrashein, in Gizeh Province, Ibshaway, in the Fayoum, Wasta and Beba, in Beni-Suef Province.

Abu Kerkas, in Minia Province, was found to be slightly infested with pink bollworm and also Assiut and Mallawi, in Assiut Province.

On the other hand, Girga, in Girga Province, still remained free or fairly so, since 100 green bolls from Sohag and 74 from Girga at the end of September contained no pink bollworms.

In 1914, 178 bolls received from Girga on September 9th contained a single pink bollworm, so unless this single larva had found its way into this parcel of bolls from some other source, the pest now occurs 300 miles south of Cairo.

ADAPTABILITY OF THE PINK BOLLWORM AND THE DANGER OF ITS BECOMING A COSMOPOLITAN COTTON PEST.

The distribution map shows that *Gelechia gossypiella* is already an inhabitant of all the chief cotton growing areas of the world except the United States of America, South America and China. It would not, however, be surprising to learn that it already occurs in the last named country.

As regards the United States of America and South America the utmost

Table II.

Effect of Low Temperatures on the Pink Bollworm.

DATE.	DEGREE OF COLD TO WHICH LARVÆ WERE SUBJECTED.	LENGTH OF EXPOSURE IN FREEZING CHAMBER.	NUMBER OF PINK BOLLWORMS WHICH SURVIVED TREATMENT.	NUMBER OF PINK BOLLWORMS KILLED BY COLD.	PER CENT KILLED BY COLD.	REMARKS.
March 13-15.	1° rising 11° F.	17 h. 30 m.	0	15	100	Larvæ in «double-seeds» (cotton) enclosed in muslin.
— —	10° falling 1° F.	30 m.	0	15	100	Naked larvæ enclosed in piece of muslin.
April 8-15.	6° — 1° F.	1 h. 25 m.	23	7	23.3	
— —	1° rising 2° F.	3 h. 50 m.	0	36	100	
— —	2° — 34° F.	40 h.	0	31	100	
— 29.	1° rising 2° F.	30 m.	34	5	12.8	
— —	2° F.	1 h.	10	16	61.5	Larvæ in «double-seeds» (cotton) enclosed in muslin.
— —	2° F.	2 h.	0	32	100	
— —	2° F.	2 h. 45 m.	0	21	100	
— 30.	2° rising 37° F.	24 h.	37	0	0	
June 12.	1°	1 h.	11	0	0	
— 13.	15° rising 35° F.	21 h.	13	0	0	
July 1.	1° rising 5° F.	30 m.	5	15	75	Naked larvæ enclosed in muslin.
—	— —	30 m.	8	0	0	Larvæ in «double-seeds» in muslin.
—	1° — 2° F.	1 h.	3	9	75	— — —
—	1° — 2° F.	1 h.	0	20	100	Naked larvæ enclosed in muslin.
—	1° — 10° F.	1 h. 30 m.	0	20	100	— — —
—	1° — 10° F.	1 h. 30 m.	1	12	92.3	Larvæ in «double-seeds» enclosed in muslin.
—	1° — 10° F.	2 h.	1	8	88.8	— — —
—	1° — 10° F.	2 h.	0	20	100	Naked larvæ enclosed in muslin.

care will have to be observed to prevent the introduction of this pest into the cotton growing states in one or more of the possible ways by which it may be disseminated.

If the pink bollworm once gained a footing in the Southern States it would stand a good chance of becoming firmly established and might well prove to be as serious a pest to cotton as the notorious Mexican cotton-boll weevil.

The climate being suitable for commercial cotton growing there seems no particular reason or reasons to doubt that it would not also be favourable to *Gelechia gossypiella*. It is true that frosts occur in some parts of the cotton growing belt; but nothing approaching sufficient severity to seriously inconvenience this species would be experienced, since this insect appears to be particularly resistant or adaptable to both heat and cold.

The pink bollworm when inclosed in the seed or a dead cotton boll can stand great cold for short periods and a temperature of freezing for many hours without being seriously affected. Gough [14] states that he has subjected larvæ to -6° F. for two hours without effect.

The following Table II shows the effect of cold on pink bollworms, naked and enclosed in double seeds. It should be noted, however, that these experiments were carried out when the temperature was high; at lower air temperatures, such as prevail in the winter when the larvæ are more dormant, results might be quite different owing to the larvæ being more resistant to the effect of cold when in this condition. It is rather surprising and says a lot for their powers of resistance that these bollworms can be taken from a temperature of 75° F., plunged suddenly into a temperature of almost zero, frozen stiff, removed and quickly thawed at 75°, and yet some may survive.

So far there is no cosmopolitan pest of cotton of a really serious nature, but unless extreme caution is practiced by those countries which grow this crop as regards the introduction of cotton seed, raw cotton, etc., it would seem that *Gelechia gossypiella*, owing to its habits and powers of resistance, has a good chance of eventually gaining this distinction.

Table III.

Progressive Severity of the Pink Bollworm attack in Lower and Upper Egypt 1912 to 1914.

LOCALITY.	1912.				1913.			1914.		
	DATE BOLLS EXAMINED.	TOTAL NUMBER OF BOLLS EXAMINED.	NUMBER OF BOLLS ATTACKED BY THE PINK BOLLWORM.	PER CENT ATTACKED.	TOTAL NUMBER OF BOLLS EXAMINED.	NUMBER OF BOLLS ATTACKED BY THE PINK BOLLWORM.	PER CENT ATTACKED.	TOTAL NUMBER OF BOLLS EXAMINED.	NUMBER OF BOLLS ATTACKED BY THE PINK BOLLWORM.	PER CENT ATTACKED.
Behera Province.....	September.	505	80	16	447	270	60	200	109	54
Gharbia —	—	545	27	5	444	177	39	201	131	64
Dakahlia —	—	232	14	6	360	119	33	201	131	65
Sharkia —	—	616	32	5	687	249	36	141	112	80
Menoufia —	—	305	6	2	687	277	40	291	160	55
Kalubia —	—	170	12	7	847	402	47	251	214	85
Giza —	November.	446	130	30	380	115	30	100	100	100
Beni Suef —	—	»	»	»	223	52	23	200	111	55
Fayoum —	—	54	15	27	90	29	32	200	33	16
Minia —	—	334	0	0	200	41	20	334	102	30
Assiut —	—	400	0	0	200	31	15	»	»	»
Girga —	—	»	0	0	174	0	0	178	1	0.5

THE PROGRESSIVE SEVERITY OF THE PINK BOLLWORM ATTACK IN LOWER AND UPPER EGYPT FROM 1912 TO 1914.

The figures given in Tables III and IV illustrate the progress of the pink bollworm attack during the past three years, they are based on the examination of green bolls obtained from various localities in Lower and Upper Egypt through the agency of the Inspectors and Store-keepers of the Society. In presenting these figures two things must be pointed out :—

1. That the taking of the samples was not carried out under the supervision of the writer nor of his assistants and so it is impossible to say to what extent the bolls were selected. The instructions given in 1913 and 1914 were that from one to two hundred bolls were to be taken at hazard from a large number of plants, and special stress was laid on the fact that on no account were evidences of attack to be looked for on the bolls before they were picked. On the whole it is believed that these instructions were carried out and that the figures obtained are of value as showing the progressive severity of the pink bollworm attack during the past three years.

2. It must be borne in mind that the percentage of attacked bolls must not be taken as indicating the actual loss to the crop, since many attacked bolls produce pickable fibre — some give almost the normal weight and quality, others much less in both respects and some of course will produce no pickable fibre.

In Table III the results of the examination of bolls from a number of localities in each Province during the month of December are given.

In Table IV the figures for one locality only in each Province are recorded.

Table IV.

Progressive Severity of the Pink Bollworm attack in Lower and Upper Egypt 1912 to 1914.

LOCALITY FROM WHICH BOLLS WERE RECEIVED.	1912.				1913.				1914.			
	DATE BOLLS EXAMINED.	TOTAL NUMBER OF BOLLS EXAMINED.	NUMBER OF BOLLS ATTACKED BY PINK BOLLWORM.	PER CENT ATTACKED.	DATE BOLLS EXAMINED.	TOTAL NUMBER OF BOLLS EXAMINED.	NUMBER OF BOLLS ATTACKED BY PINK BOLLWORM.	PER CENT ATTACKED.	DATE BOLLS EXAMINED.	TOTAL NUMBER OF BOLLS EXAMINED.	NUMBER OF BOLLS ATTACKED BY PINK BOLLWORM.	PER CENT ATTACKED.
Behera Province:												
Damanhour...	September	27	17	63	September 28	100	40	40	September 7	200	109	54.5
Gharbia Province:												
Dessouk.....	—	20	6	30	— 24	156	51	32	— 9	201	131	65
Dakahlia Province:												
Mit Ghamr....	—	97	8	8	— 15	100	37	37	— 9	201	131	65
Sharkia Province:												
Zagazig.....	—	100	6	6	— 15	100	27	27	— 8	141	114	81
Menoufia Province:												
Batanoun.....	—	60	1	1.6	— 24	200	110	55	— 7	291	160	55
Kalubia Province:												
Benha.....	—	96	10	10	— 15	20	9	45	— 19	251	214	85
Giza Province:												
Giza.....	November	96	3	3	"	"	"	"	October 26	100	100	100
Fayoum Province:												
Fayoum.....	—	54	15	27	"	"	"	"	"	"	"	"
Ibshaway.....	—	"	"	"	September 17	90	32	35	September 8	200	34	17
Minia Province:												
Minia.....	—	334	0	0	"	"	"	"	— 21	140	97	69
Abu Kerkas...	—	"	"	"	September 18	200	40	20	— 9	194	7	4

THE PROPORTION OF THE BOLLWORMS *EARIAS INSULANA* AND *GELECHIA GOSSYPIELLA* IN COTTON BOLLS FROM INFESTED COTTON FIELDS 1912 TO 1914.

The following Table V is of interest showing as it does the numbers of these two destructive species in cotton fields in various parts of Upper and Lower Egypt during the past three years. In 1912 it will be seen that the ordinary bollworm *Earias insulana* was quite common and in most cases equal to or greatly in excess of the pink bollworms (*Gelechia gossypiella*). In 1913 *Earias* was quite rare, comparatively speaking, and altogether outnumbered by *Gelechia*. The same state of affairs was noticed in 1914, only in some cases the difference was still more marked in favour of the latter species. It is exceedingly fortunate for Egypt that *Earias insulana* has been, practically speaking, rare during the past two years of very severe pink bollworm attack. If *Earias* had been anything like as common as the pink bollworm or as numerous as it (*Earias*) was in 1905 and 1909 the damage to the crop would have been increased enormously and the result would have been a disaster for the country.

THE NUMBER OF PINK BOLLWORMS FOUND PER ATTACKED BOLL.

The following Tables VI and VII show the number of pink bollworms which may be found per attacked green or unripe boll. Each table is in two parts: in the first, only the actual number of larvæ found per boll have been recorded; in the second half the exit holes in the boll have been reckoned also as being equivalent to a pink bollworm. The figures in Table VI are for bolls from a single locality, viz., the Society's Farm

Table V.

Comparison between the Number of *Earias* Larvæ and the Number

PROVINCES.	DATE.	1912.					
		NUMBER OF BOLLS EXAMINED.	TOTAL NUMBER OF *EARIAS* AND *GELECHIA* FOUND.	NUMBER OF *EARIAS* LARVÆ.	PER CENT OF TOTAL.	NUMBER OF *GELECHIA* LARVÆ.	PER CENT OF TOTAL.
Lower Egypt.							
Behera	September.	505	185	84	**45.4**	101	**54.6**
Gharbia	—	545	150	118	**78.6**	32	**21.4**
Menoufia	—	305	103	97	**94.2**	6	**5.8**
Dakahlia	—	232	60	46	**76.6**	14	**23.4**
Sharkia	—	616	239	200	**83.6**	39	**16.4**
Kalubia	—	170	49	35	**71.4**	14	**28.6**
Behera	November.	1,321	1,621	346	**21.3**	1,275	**78.7**
Gharbia	—	1,420	1,043	622	**59.6**	421	**40.4**
Menoufia	—	548	404	245	**60.6**	159	**39.4**
Dakahlia	—	934	1,081	391	**36.2**	690	**63.8**
Sharkia	—	297	213	140	**65.7**	73	**34.3**
Kalubia	—	97	39	14	**35.9**	25	**64.1**
Upper Egypt.							
Gizeh	September.	"	"	"	"	"	"
Beni Suef	—	"	"	"	"	"	"
Fayoum	—	"	"	"	"	"	"
Assiut	—	"	"	"	"	"	"
Girga	—	"	"	"	"	"	"
Minia	—	"	"	"	"	"	"
Gizeh	November.	446	227	90	**39.6**	137	**60.4**
Beni Suef	—	"	"	"	"	"	"
Fayoum	—	54	56	37	**66**	19	**34**
Assiut	—	400	72	72	**100**	0	**0**
Girga	—	"	"	"	"	"	"
Minia	—	334	122	122	**100**	0	**0**

OF *GELECHIA* LARVÆ FOUND IN COTTON FIELDS 1912 - 1914.

1913.						1914.					
NUMBER OF BOLLS EXAMINED.	TOTAL NUMBER OF *EARIAS* AND *GELECHIA* LARVÆ.	NUMBER OF *EARIAS* LARVÆ.	PER CENT OF TOTAL.	NUMBER OF *GELECHIA* LARVÆ.	PER CENT OF TOTAL.	NUMBER OF BOLLS EXAMINED.	TOTAL NUMBER OF *EARIAS* AND *GELECHIA* LARVÆ.	NUMBER OF *EARIAS* LARVÆ.	PER CENT OF TOTAL.	NUMBER OF *GELECHIA* LARVÆ.	PER CENT OF TOTAL.
447	370	9	**2.4**	361	**97.6**	200	91	0	**0**	91	**100**
644	319	9	**2.8**	310	**97.2**	201	97	2	**2**	95	**98**
687	484	17	**3.5**	467	**96.5**	291	181	17	**9.3**	164	**90.7**
579	378	22	**5.8**	356	**94.2**	201	157	7	**4.4**	150	**95.6**
687	180	24	**13.3**	156	**86.7**	141	155	1	**0.6**	154	**99.4**
1,267	529	29	**5.4**	500	**94.6**	1,500	516	10	**1.9**	506	**98.1**
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
580	311	38	**12.2**	273	**87.8**	"	"	"	"	"	"
223	37	14	**37.8**	23	**62.2**	200	145	14	**9.6**	131	**90.4**
90	29	1	**3.4**	28	**96.6**	200	33	1	**3**	32	**97**
200	29	1	**3.4**	28	**96.6**	"	"	"	"	"	"
174	2	2	**100**	0	**0**	178	7	6	**85.7**	1	**14.3**
200	16	1	**6.2**	15	**93.8**	334	135	13	**9.6**	122	**90.4**
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"

Table VI.

Number of Pink Bollworms found per attacked

LOCALITY.	DATE.	NUMBER OF ATTACKED BOLLS EXAMINED.	NUMBER OF BOLLS CONTAINING 1 LARVA PER BOLL.	PER CENT OF TOTAL.	NUMBER OF BOLLS CONTAINING 2 LARVÆ PER BOLL.	PER CENT OF TOTAL.	NUMBER OF BOLLS CONTAINING 3 LARVÆ PER BOLL.	PER CENT OF TOTAL.
Exit Holes not Counted as								
1913 Bahtim.	July	2	2	100	"	"	"	"
	August	6	6	100	"	"	"	"
	September	177	157	88.7	16	9	4	2.3
	October	517	261	50.5	138	26.6	79	15.3
	Totals 1913	702	426	60.07	154	21.9	83	11.8
Average Number of								
1914 Bahtim.	July	14	12	85.7	2	14.3	"	"
	August	23	23	100	"	"	"	"
	September	1,158	656	56.6	296	25.5	124	10.7
	October	273	128	46.9	54	19.7	50	18.3
	Totals 1914	1,468	819	55.7	352	24	174	11.8
Average Number of								
Exit Holes Counted as								
1913 Bahtim.	October	572	246	43	174	30.5	103	18
Average Number of								
1914 Bahtim.	September	1,616	678	42	474	29.4	250	15.4
	October	294	129	43.9	58	19.7	58	19.7
	Totals	1,910	807	42.2	532	28	308	16
Average Number of								

* 9 Larvæ in this boll.
** 12 — — —

Green Boll at Bahtim 1913-1914.

Number of bolls containing 4 larvæ per boll.	Per cent of total.	Number of bolls containing 5 larvæ per boll.	Per cent of total.	Number of bolls containing 6 larvæ per boll.	Per cent of total.	Number of bolls containing 7 larvæ per boll.	Per cent of total.	Number of bolls containing 8 larvæ per boll.	Per cent of total.	Number of bolls containing more than 8 larvæ per boll.	Per cent of total.
Equivalent to a Pink Bollworm.											
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
26	5	9	1.8	2	0.4	"	"	2	0.4	"	"
26	3.7	9	1.3	2	0.3	"	"	2	0.3	"	"
Larvæ per boll = 1.65.											
"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"
61	5.3	16	1.4	5	0.5	"	"	"	"	"	"
24	8.8	5	1.8	7	2.6	3	1.1	2	0.8	"	"
85	5.8	21	1.5	12	0.9	3	0.2	2	0.1	"	"
Larvæ per boll = 1.77.											
Equivalent to a Pink Bollworm.											
21	3.6	20	3.5	6	1.06	1	0.17	0	"	1*	0.17
Larvæ per boll = 1.99.											
135	8.3	51	3.2	21	1.3	5	0.3	2	0.1	"	"
26	9	8	2.7	9	3	3	1	2	0.7	1**	0.3
161	8.5	59	3.1	30	1.5	8	0.43	4	0.22	1	0.05
Larvæ per boll = 2.10.											

Table VII.

Number of Pink Bollworms found per attacked Green Boll 1913 and 1914 in Bolls from many Localities.

DATE.	NUMBER OF ATTACKED BOLLS EXAMINED.	NUMBER OF BOLLS CONTAINING 1 LARVA PER BOLL.	PER CENT OF TOTAL.	NUMBER OF BOLLS CONTAINING 2 LARVÆ PER BOLL.	PER CENT OF TOTAL.	NUMBER OF BOLLS CONTAINING 3 LARVÆ PER BOLL.	PER CENT OF TOTAL.	NUMBER OF BOLLS CONTAINING 4 LARVÆ PER BOLL.	PER CENT OF TOTAL.	NUMBER OF BOLLS CONTAINING 5 LARVÆ PER BOLL.	PER CENT OF TOTAL.	NUMBER OF BOLLS CONTAINING 6 LARVÆ PER BOLL.	PER CENT OF TOTAL.	NUMBER OF BOLLS CONTAINING 7 LARVÆ PER BOLL.	PER CENT OF TOTAL.	NUMBER OF BOLLS CONTAINING 8 LARVÆ PER BOLL.	PER CENT OF TOTAL.	NUMBER OF BOLLS CONTAINING MORE THAN 8 LARVÆ PER BOLL.	PER CENT OF TOTAL.
Year 1913. — Exit Holes not Counted as Equivalent to a Pink Bollworm.																			
July.....	2	2	100	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
August....	6	6	100	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
September.	1,999	1,577	78.8	290	14.5	97	4.8	27	1.5	4	0.2	3	0.15	1	0.05	"	"	"	"
October...	798	443	55.5	219	27.5	91	11.5	30	3.7	12	1.5	1	0.1	1	0.1	1	0.1	"	"
November..	223	65	29	79	35.5	47	21	13	5.8	11	5	6	2.7	1	0.5	"	"	1*	0.5
December..	55	37	67.3	13	23.6	4	7.3	1	1.8	"	"	"	"	"	"	"	"	"	"
Totals..	3,083	2,130	69.09	601	19.49	239	7.75	71	2.31	27	0.88	10	0.33	3	0.09	1	0.03	1	0.03
Average Number of Larvæ per attacked boll = 1.48.																			
Exit Holes Counted as Equivalent to a Pink Bollworm.																			
July.....	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
August....	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
September.	708	453	63.9	172	24.3	67	9.5	14	2	2	0.3	"	"	"	"	"	"	"	"
October...	1,033	459	44.5	329	31.8	167	16.1	42	4.03	24	2.4	9	0.9	1	0.09	1	0.09	1*	0.09

November..	237	43	18.2	52	21.9	70	29.5	40	16.9	12	5	13	5.5	5	2.2	1	0.4	1	0.4
December..	70	51	73	14	20	3	4	1	1.5	"	"	1	1.5	"	"	"	"	"	"
Totals..	2,048	1,006	49.1	567	27.6	307	15	97	4.7	38	2	23	1.2	6	0.22	2	0.09	2	0.09

Average Number of Larvæ per attacked boll = 1.84.

Year 1914. — Exit Holes not Counted as Equivalent to a Pink Bollworm.

July.....	14	12	85.7	2	14.3	"	"	"	"	"	"	"	"	"	"	"	"	"	"
August....	23	23	100	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
September.	1,804	1,091	60.5	459	25.4	167	9.2	66	3.7	14	0.8	6	0.34	1	0.06	"	"	"	"
October...	306	120	39.3	83	27.2	58	19	24	7.8	11	3.6	5	1.6	3	0.9	1	0.3	1*	0.3
November..	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
December..	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Totals..	2,147	1,246	58.03	544	25.34	225	10.48	90	4.19	25	1.18	11	0.52	4	0.18	1	0.04	1	0.04

Average Number of Larvæ per attacked boll = 1.67.

Exit Holes Counted as Equivalent to a Pink Bollworm.

July.....	30	28	93	2	7	"	"	"	"	"	"	"	"	"	"	"	"	"	"
August....	54	54	100	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
September.	2,511	1,218	48.5	706	28.2	335	13.3	158	6.3	60	2.37	26	1.03	6	0.23	2	0.07	"	"
October...	393	155	39.4	72	18.3	90	23	39	10	14	3.5	14	3.5	6	1.5	2	0.5	1*	0.3
November..	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
December..	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Totals..	2,988	1,455	48.6	780	26.2	425	14.3	197	6.5	74	2.44	40	1.3	12	0.5	4	0.13	1	0.03

Average Number of Larvæ per attacked boll = 1.94.

9* Larvæ found in these bolls.

at Bahtim, near Cairo. Table VII includes bolls from many localities in all parts of Egypt.

Generally speaking, the bolls examined were large and well advanced towards maturity and the exit holes in them were in most cases fresh cut showing that the larvæ had left but a short time before the bolls were examined.

As might be expected, the number of larvæ infesting a boll varies according to the stage of attack and the density of the bollworm population. In July and August it is usual to find only one pink bollworm in an attacked boll, but in September from one to seven may occur, and in October as many as nine or twelve may inhabit a single boll. In November and December the tendency seems to be for the number to fall again and ones or twos become most common. As a rule, at any time the most common number of larvæ to find per attacked boll is from one to three. The damage caused by three larvæ in a boll is very serious as in a great number of cases all three locks will be affected; even one larva may often cause injury to all three sections of the boll partly by direct attack and partly by causing proliferation.

Tables VI and VII show that the attack in 1914 was slightly more severe than in 1913. It is doubtful, however, if the density of the bollworm population per boll is of very much value as a guide to determine the severity of the attack from year to year.

LOSS CAUSED BY THE PINK BOLLWORM.

The difficulty of assessing the monetary losses caused by insect pests is well known to all economic entomologists. It is this difficulty perhaps, which accounts for — speaking in a general way — the lack of attempts to make out «loss accounts» against insect pests in the literature dealing with their economy. An insect pest which attacks to a serious extent a vast commercial crop like cotton not only causes a direct loss by reducing the quantity and quality of the yield, but it also gives rise to all kinds of what may be termed indirect losses which ramify in all directions. For

example, there is the loss to the railway and steamship companies to the extent of the value of the freights on that part of the crop destroyed by the pest. Similarly the ginning companies suffer, as they have a smaller crop to deal with and so earn less money. This in turn also affects the coal merchant, since the machinery being run for a shorter time the fuel consumption will be less, not to mention oil, etc.

Again the cultivator realizes a much less amount of money for his crop and in consequence his spending power is less, which will affect all sorts of persons and trades. He even may be unable to pay the rent of his land and thus the landlord will be affected and through him a lot of other people as well perhaps.

The ways in which man is affected by the attack of an insect on an important crop such as cotton might be extended almost indefinitely, but the simple examples cited will serve to show how difficult and in fact how impossible it is to reach a comprehensive and accurate estimate of the money loss caused by an injurious insect. On the other hand, in the case of pests like the cotton bollworms, whose destructive work on the crop is so apparent, it is not a difficult matter to obtain a closely approximate figure for the loss in yield suffered by a crop in a particular field, because we can take a representative number of plants, count and weigh the sound and attacked bolls and so make our calculation for the whole area. This has been done in the case of the pink bollworm and as will be seen later the loss due to the working of this insignificant looking insect is astonishing, and will in all probability be doubted by many.

Nature of the losses caused by the pink bollworm. — The losses caused by this pest may be considered under two heads :—

A. Direct losses to the crop.

B. Indirect losses incidental to a reduced crop.

Group A may be sub-divided as follows :—

a. Loss to the fibre { 1. as regards quality. 2. as regards quantity or weight.

b. Loss to the seed { 1. as regards quality. 2. as regards quantity or weight.

a. Loss to the fibre.

1. Loss in quality of the fibre. — Loss in quality owing to the attacks of the pink bollworm may result in two ways :—

a. In many cases the cotton fibre in bolls injured by this pest does not «fuzz out» (Plate VIII, Figs. 1 and 12) but remains in a hard and often closely felted lock (Plate VIII, Fig. 13) which may or may not exhibit visible signs of the work of the bollworm. The fibre of these damaged locks is, generally speaking, discoloured to a brownish or rusty hue and occasionally it is black and rarely dark red or wine-coloured. The fibres tend to be irregular and short and moreover, they are weak, sometimes almost rotten. The value of a sample of cotton is much reduced if much of this injured fibre — the so-called «dead» or «mabruma» cotton is present; the value being diminished from one to three dollars per kantar of the first picking and much more in the case of the late pickings. Large cultivators usually have this inferior fibre picked out — an operation in itself costing some 10-15 piastres per kantar — and sold separately. It fetches as a rule about 100 to 130 or perhaps as much as 160 piastres* per kantar as against 360 to 400 piastres for good seed-cotton.

b. The second way in which the quality of the cotton may be affected is during the ginning process, which separates the seeds from the fibre. It appears that there is a tendency for the damaged seeds to break up into small pieces and pass through the gins along with the fibre and becoming mixed with the latter rather spoils its appearance**.

Similarly, certain of the bollworm injured or «mabruma» locks of seed-cotton, which have fuzzed out slightly, are caught between the knife blade and the roller and are thus ginned. The bad fibre passing through

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* A piastre = 2 $\frac{1}{2}$ pence.

** The amount of broken seed and mabruma fibre passing through the gins will depend a good deal on the «setting» of the latter. The «setting» has to be varied according to the variety being ginned, the picking, kind of sample desired, etc.

with the good gives rise not only to discoloured areas in the latter but also areas in which there is likely to be considerable irregularity in the length and strength of the fibres. The discolouration or spottiness in a ginned sample of cotton is most marked when a white variety is concerned, such as «Sakellaridis» for example*. Fortunately the great majority of the hard mabruma locks of fibre and seed, which have not fuzzed out at all, fall back with the seed and are carried away to the scarto gins. Here most of them are broken up the seed being cleanly separated from the fibre in the case of first picking cotton, but in the second and third pickings in which the proportion of dead cotton is very high indeed some of the hard locks and partially ginned seed may be returned with the seed from the scarto gins**.

The good cotton may be injured to a certain extent in yet another way during the ginning process. In the first picking there are always a number of pink bollworms which have not reached maturity before the crop is gathered. These larvæ on completing their growth leave the seeds and wander about amongst the seed-cotton when the latter is in the stores waiting to be ginned. Some of these pink bollworms spin cocoons amongst the fibres which are thus woven together into more or less of a tangle. During ginning the free larvæ are dragged through the gin along with the cotton and are squashed flat in the process, the spot where their death took place being marked by a pink discolouration of the fibre, which as it dries becomes matted and harsh to the touch at this point. Whether or not the body juices of the squashed larvæ cause any change in the strength of the fibres has get to be learnt. The pupæ and pupating larvæ in the cocoons spun in the seed-cotton are also crushed in the passage through the gins thus giving rise to discolouration as well as tangling of the fibres.

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* See p. 44, footnote**.

** This question depends a good deal on the kind of scarto gin employed. The American saw-toothed gin separates the lint from the seed of the mabruma locks of seed-cotton in a very thorough manner indeed.

The number of free larvæ and larvæ or pupæ in cocoons in raw cotton will vary according to the severity of the attack and also the date when the first picking is taken. Fortunately they will not be present, generally speaking, in sufficient numbers to cause a deterioration in the ginned fibre which can be described as really serious.

I am informed that there appears to be a tendency for the free pink bollworms to be most numerous in first picking cotton and less so in the second and third pickings. If this is really the case, it is due in all probability to the fact that in the late pickings a much larger proportion of the larvæ will enter the resting or quiescent larval stage and consequently will remain and spin cocoons in the interior of the seeds in which they were feeding at the time when the cotton was gathered from the plants. Inside the seeds these larvæ are practically safe from destruction during the ginning of the seed-cotton, passing through the entire process with the seed.

The quantity of bad seed-cotton in a sample will depend of course on the severity of the attack and on the picking — first, second or third.

In 1913 a sample of 1,198 grammes of first picking Assili cotton from the Society's Farm at Bahtim there were only 13 grammes or 1 per cent of bad quality fibre that had been obviously damaged by the pink bollworm. In the second picking in a sample of 1,281 grammes there were 100 grammes or 7 per cent damaged fibre.

In 1914, owing to a more severe attack, the figures are higher. In a sample of 3,956 grammes 1st picking Assili from the same farm there was a weight of 254 grammes or 6.4 per cent of much inferior fibre. In the same weight of 2nd picking there were 1,424 grammes or 35.9 per cent of obviously damaged fibre and even when this had been removed the «cleaned sample» was still very inferior in appearance. The photographs (Figs. 2 and 3 on Plate IX) illustrate these figures graphically.

When it is considered that the damaged fibre is worth some L. Eg. 2 less per kantar it will be readily realized to what a great extent the Egyptian cotton crop has suffered as regards quality during the past two or three years of severe attack by the pink bollworm.

2. Loss in weight of fibre produced per boll. — The loss in weight of the fibre produced by an attacked boll will depend on the picking to which it belongs — another way of saying to the number of bollworms by which has been invaded. In the case of the first picking bolls the loss is sometimes so slight as regards the production of fibre as to be almost negligible. On the other hand, in the worst cases little or no fibre is produced — that is to say pickable fibre. Plate VIII Figs. 6, 7, and 8 illustrate bolls in which there is fibre that would not be picked as it is worthless, consisting as it does of a few poorly developed fibres mixed up with proliferation tissue into a small hard lock (Plate VIII, Fig. 13).

The first picking bolls are least affected because so many of them are invaded by one larva only, which will as often as not confine its injurious work to one section or lock and perhaps to one division of that lock. Such bolls produce almost, if not quite, a normal weight of fibre the quality of which appears to be unaffected, but whether this is really so has yet to be ascertained; not improbably the fibre suffers as regards strength. From a casual inspection these bolls appear quite sound and it is only when one separates the fibre from the seeds and examines the latter that one finds the boll has been attacked. In the calculations — see Table XIV — a column will be found headed «Bolls slightly attacked, practically sound». Under this heading are included all bolls originally set aside as being sound, but which subsequently during the detailed examination were found to have injured seeds in them.

The damage and consequent loss in weight to the second picking bolls is much heavier owing to the larger average number of larvæ attacking them : this results in more locks and divisions being affected. Furthermore, the work of the larvæ is accentuated by the increased humidity at this season and the consequent tendency for rot and fermentation to be set up in the interior. In 1,416 second picking green bolls examined at the time the first picking was collected it was found that the average number of divisions (6 divisions to the 3 sections or locks) attacked and injured to a greater or less extent was 3.33. In the third picking

Table VIII.

RESULTS OF A DETAILED EXAMINATION, GIVING WEIGHT OF PRODUCE, ETC., FROM SOUND AN

NUMBER OF BOLLS PRODUCED.				WEIGHTS OF TOTAL PRODUCE FROM 24 PLANTS.							PRODUCE FROM SOUND BOLLS FREE FROM ALL SIGN OF ATTACK BY THE PINK BOLLWORM.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
NUMBER PLANTS EXAMINED.	TOTAL NUMBER OF BOLLS PRODUCED ON (1).	NUMBER SOUND BOLLS.	NUMBER ATTACKED BOLLS.	TOTAL WEIGHT SEED-COTTON FROM (3) AND (4).	TOTAL WEIGHT FIBRE FROM (3) AND (4).	TOTAL WEIGHT SEED FROM (3) AND (4).	WEIGHT GOOD FIBRE FROM (3) AND (4).	WEIGHT BADLY DAMAGED FIBRE (*UNPICKABLE*) FROM (4).	WEIGHT SOUND SEED FROM (4).	WEIGHT OF ATTACKED SEED FROM (4).	NUMBER OF SOUND BOLLS.	TOTAL WEIGHT SEED-COTTON FROM (12).	WEIGHT FIBRE FROM (13).
24 from 12 'Nogras'	393 = 16.37 bolls per plant.	230 = 58.5 % of (2).	163 = 41.5 % of (2).	860.315 grams.	291.5939 grams = 34 % of (5).	568.7211 grams = 66 % of (5).	270.6509 grams = 92.8 % of (6).	20.943 grams = 7.2 % of (6).	501.7211 grams = 88.2 % of (7).	67 grams = 11.8 % of (7).	230	580.351 grams = 2.522 per boll = 0.8406 per lock " 67.45 % of (5).	199.9601 grams = 0.869 per boll = 0.2896 per lock " 23.24 % of (5) and 34.45 % of (13).

Attacked Ripe Bolls of First Picking, of 24 Assili Cotton Plants, Bahtim, 1914.

PRODUCE FROM SOUND BOLLS FREE FROM ALL SIGN OF ATTACK BY THE PINK BOLLWORM.		PRODUCE FROM BOLLS ATTACKED AND INJURED BY THE PINK BOLLWORM.												
15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
WEIGHT SEED FROM (13).	NUMBER OF SEEDS IN (15).	NUMBER ATTACKED BOLLS.	TOTAL WEIGHT SEED-COTTON FROM (17).	WEIGHT FIBRE (18).	WEIGHT SEED (18).	TOTAL NUMBER SEEDS IN (18).	NUMBER SOUND SEEDS IN (21).	NUMBER ATTACKED SEEDS IN (21).	NUMBER AND PRODUCE SOUND LOCKS SEED-COTTON IN (17).	NUMBER AND PRODUCE SLIGHTLY INJURED LOCKS, SEED-COTTON IN (17).	NUMBER AND PRODUCE BADLY INJURED LOCKS SEED-COTTON IN (17) *UNPICKABLE.*	NUMBER BOLLS 1 LOCK BADLY INJURED (*FIBRE UNPICKABLE*).	NUMBER BOLLS 2 LOCKS BADLY INJURED (*FIBRE UNPICKABLE*).	NUMBER BOLLS 3 LOCKS BADLY INJURED (*FIBRE UNPICKABLE*).
380.3909 grams = 1.653 per boll = 0.551 per lock » **44.21 %** of (5) and **65.55 %** of (13).	3,530 = 15.34 per boll.	163	279.964 grams = 1.716 per boll = 0.572 per lock » **32.5 %** of (5).	91.6338 grams = 0.562 per boll = 0.1873 per lock » **32.73 %** of (18) and **31.42 %** of (6).	188.3302 grams = 1.154 per boll = 0.3847 per lock » **67.27 %** of (18) and **33.11 %** of (7).	2,337 = 14.3 per boll.	1,177 = 7.2 per boll = **50.32 %** of (21).	1,160 = 7.1 per boll = **49.68 %** of (21).	93 = 70.116 grams seed-cotton = **8.15 %** of (5) » 23.763 grams Fibre = **33.8 %** and **8.77 %** of (8) 46.353 grams seed = **66.2 %**	204 = 139.418 grams seed-cotton = **16.20 %** of (5) » 46.9278 grams Fibre = **33.7 %** and **17.33 %** of (8) 92.4902 grams seed = **66.3 %**	193 = 70.430 grams seed-cotton = **8.18 %** of (5) » 20.943 grams Fibre = **29.7 %** and **7.2 %** of (6) 49.487 grams seed = **70.3 %**	51 = **31.3 %** of (4) = **12.9 %** of (2).	29 = **17.7 %** of (4) = **7.3 %** of (2).	28 = **17.1 %** of (4) = **7.1 %** of (2).

Table IX.

Weight of Produce per Lock in Attacked Bolls - Assili Cotton - 1914.

WEIGHT OF PRODUCE OF SOUND LOCKS IN ATTACKED BOLLS.						WEIGHT OF SLIGHTLY ATTACKED LOCKS IN ATTACKED BOLLS.				WEIGHT OF BADLY ATTACKED LOCKS IN ATTACKED BOLLS.			
1 NUMBER OF PLANTS.	2 NUMBER OF BOLLS EXAMINED.	3 NUMBER OF SOUND LOCKS OF SEED COTTON IN 2.	4 TOTAL WEIGHT OF FIBRE AND SEED.	5 TOTAL WEIGHT OF FIBRE.	6 TOTAL WEIGHT OF SEED.	7 NUMBER OF SLIGHTLY ATTACKED LOCKS IN 2.	8 TOTAL WEIGHT OF FIBRE AND SEED.	9 TOTAL WEIGHT OF FIBRE.	10 TOTAL WEIGHT OF SEED.	11 NUMBER OF BADLY ATTACKED LOCKS IN 2.	12 TOTAL WEIGHT OF FIBRE AND SEED.	13 TOTAL WEIGHT OF FIBRE.	14 TOTAL WEIGHT OF SEED.
12	163	93	70.116 grams = 0.7539 per lock.	23.763 grams = 0.2555 per lock.	46.353 grams = 0.4984 per lock.	204	139.418 grams = 0.6834 per lock.	46.9278 grams = 0.2300 per lock.	92.4902 grams = 0.4534 per lock.	193	70.430 grams = 0.3649 per lock.	20.943 grams = 0.1085 per lock.	49.487 grams = 0.2564 per lock.

green bolls — taken at the time of the second picking — the average number of the attacked divisions had risen to five. In the former case light weight sound locks of fibre might be produced by the bolls (Plate VIII, Figs. 2 and 5), but in the second no pickable fibre would be given by bolls so badly injured.

Tables VIII and IX show the average weight of produce per boll and per lock from sound and attacked bolls and also the average weights of the separate locks in attacked bolls according to whether they were sound, slightly attacked or badly attacked. The weighings were done on a chemical balance. The first operation was to separate the seed-cotton into the three locks; each lock was then ginned by hand into fibre and seed which were weighed separately. The two weights added gave the total weight per lock and the addition of the six separate weighings gave the total weight per boll, the total weight of seed and fibre per boll was recorded also. All the ripe bolls of the first picking on 12 plants taken from different parts of the field were weighed in this manner.

The average weight of cotton fibre alone per sound boll was 0.869 grammes, but from attacked bolls it averaged only 0.562 grammes, a difference of 0.307 grammes or 35 per cent on the weight of lint from a sound boll.

In badly attacked locks there may be a difference of 60 per cent between the weight of fibre from a sound and attacked boll, and as often as not in such cases this 60 per cent difference may be equivalent, practically speaking, to a loss of 100 per cent as regards the fibre, which owing to its being mixed up with the products of proliferation is not really pickable or at all events marketable.

It appears that sound locks of fibre and seed in attacked bolls weigh less than those produced by a sound boll. The average weight of fibre alone per lock, per sound boll, was 0.2896 grammes (Table VIII) and from a sound lock in an attacked boll it was 0.2555 grammes (Table IX), a difference of 0.0341 grammes or 11.7 per cent.

Table X.

The Quantity of Seed Injured by Pink Bollworm in Different Samples of Cotton Seed of 1914 Season.

Variety of Seed.	Weight of Sample Examined.	Total Number of Seeds in this Sample.	Sound Seed.				Attacked Seeds.				Approximate Weight of Injured Seed in such Samples per Ardeb and per Ton.	
			Total Number of Sound Seeds in Sample.	Per Cent of Total Seeds.	Weight of Sound Seeds.	Per Cent of Total Weight of Sample.	Total Number of Attacked Seeds in Sample.	Per Cent of Total Seeds.	Weight of Attacked Seeds.	Per Cent of Total Weight of Sample.	Per Ardeb.	Per 1000 Kilos = 1 Ton Metric.
Jannovitch I. quality.	500 grams	4,451	4,025	90.4	468 grams	93.6	426	9.6	32 grams	6.4	0.76 kelas	64 kilos
— II. —	—	5,016	3,894	77.6	424 —	84.8	1,122	22.4	76	15.2	1.8	152
III.	—	5,085	2,737	53.8	407 —	81.4	2,348	46.2	93 —	18.6	2.2 —	186
Nubari I. quality ...	—	4,604	4,045	87.8	459.2	91.8	559	12.2	40.8	8.2	0.97	81.6
— II. ...	—	5,489	3,960	72.1	396	79.2	1,529	27.9	104	20.8	2.5	208
III. ...		5,415	2,901	53.5	317	63.4	2,514	46.5	183	36.6	4.38	366
A66 I. quality		5,073	4,410	86.9	455	91	663	13.1	45	9	1	90
— II. —	—	5,350	3,773	70.5	389.5	77.9	1,577	29.5	110.5	22.1	2.6	221
III.	— —	5,471	4,027	73.6	407	81.4	1,444	26.4	93	18.6	2.2	186
Voltos I. quality....		5,912	4,094	69.2	353	70.6	1,818	30.8	147	29.4	3.5 —	294
— II. —	— —	5,084	3,319	65.2	366	73.2	1,765	34.8	134	26.8	3.3 —	286 —
III.	— —	5,347	3,160	59.1	335	67	2,187	40.9	165 —	33	3.9	330 —

1 Ardeb = 5.445 bushels. — 1 Ardeb cotton seed = 260 pounds.

b. Loss to the seed.

1. Quality. — As regards the seed the matter of quality has reference chiefly to the quantity and quality of the oil content and is therefore, more a question for the chemist rather than the entomologist. Table X shows what a large quantity of damaged seed there may be in a sample of seed after a severe pink bollworm attack such as that of 1914. These samples are on the whole particularly good, but in some lots there may be 50 % or more of injured seed.

It is obvious that the same amount of oil will not be obtained from the seeds in which the kernel or oil containing part has been injured as from the sound seeds. To what extent fermentation takes place in the attacked seed whilst still in the boll and again after ginning when the seed is in bulk and how this affects the oil, if at all, has yet to be studied. The following Table XI, showing the amount of oil etc.. in samples of bollworm damaged seed and the report by Dr. Kœnig, formerly Chemist to the Society, is of interest indicating as it does that the quality as well as the quantity of oil appears to be affected as a result of the work of the pink bollworm.

Bahtim, Poste Matarieh, 20 September 1913.

Dear Mr. Willcocks,

I am glad to be able to send you herewith the report about the samples of cotton seeds you sent me. There are some differences without any doubt.

The cotton seeds infested by the Pink Boll-Worm contains generally not good oil, but there is an exception No 3 with 6 % Pink Boll-Worm contains much and good oil.

To have an exact comparison it would be advisable to examine the seed of one and the same year, from the same province, from cotton grown under the same conditions, same kind of cotton, same manure, same soil and same farming.

If these exterior conditions are the same we could have better material for comparing the results.

To show you the content and quality of the oil of a new cotton seed, I analysed at the same time our cotton seed (Assili) used in March last for sowing and another sample of cotton seed, picked on the 16th September, just the date when beginning the analysis.

I am, Dear Sir,

Very truly yours

Dr. P. Koenig.

Table XI.

The Effect of the Attack by the Pink Bollworm on the Quantity and Quality of the Oil Content of the Seed.

Analysis of Samples of Cotton Seed injured by Pink Bollworm.

NUMBER OF SAMPLE.	CONTAINING PINK BOLLWORM PER CENT.	REMARKS.	COLOUR OF THE CRUSHED SEED.	SMELL OF THE CRUSHED SEED.	QUANTITY OF FAT IN SEED DRIED AT 100° C. PER CENT.	OLEIC ACID IN DRIED SEED PER CENT.	FREE OLEIC ACID IN THE OIL PER CENT. (RANCID FROM 17-20 %)
1	5	Seed for Export (Crushing).	Grey-yellow.	Rancid.	19.7	4.120	20.9
2	6	Number 5 Behera low Quality. Seed for Crushing.	Grey-yellow.	About without smell.	21.060	2.1	10
3	Majority of seeds containing Pink Bollworms.	Picked « double seeds » from Number 5 Behera Sample.	Grey-brown.	Very rancid.	10.920	4.70	42.86
4	2.330	Nubari for Crushing.	Yellow.	Without smell.	18.130	2.260	12.440
5	1.210	3rd Picking Abbassi for Crushing.	A nice yellow.	A little rancid.	22.860	2.20	9.620
6	Not known. Probably very low. Under 0.5 %	Assili Seed 1912. Tagawi.	A nice yellow.	Without smell.	22.510	3.20	14.2
7	Not known. Probably under to about 1 %	Fresh Cotton Seed « Voltos » of 1st Picking. 17/IX/13	A nice yellow.	Without smell.	18.9	3.1	16.2

2. Loss in weight. — The weight of the seed being roughly two thirds of the total weight of the seed and fibre and moreover, the seeds being the object of the bollworm's attack, it follows that it is here that the greatest loss in weight will take place.

Reference to Table VIII will show that the average weight of seeds per sound boll was 1.653 grammes and from attacked bolls 1.154 grammes, a difference of 0.499 grammes or 30 per cent.

Table XII.

Weights of Sound Assili Cotton Seeds.

NUMBER OF SEED.	WEIGHT OF SEED.	NUMBER OF SEED.	WEIGHT OF SEED.	NUMBER OF SEED.	WEIGHT OF SEED.	NUMBER OF SEED.	WEIGHT OF SEED.
	Grams.		Grams.		Grams.		Grams.
1	0.113	15	0.100	29	0.115	43	0.117
2	0.123	16	0.127	30	0.055	44	0.137
3	0.121	17	0.110	31	0.120	45	0.111
4	0.105	18	0.119	32	0.112	46	0.116
5	0.083	19	0.120	33	0.141	47	0.129
6	0.106	20	0.126	34	0.059	48	0.121
7	0.104	21	0.133	35	0.058	49	0.125
8	0.118	22	0.118	36	0.103	50	0.087
9	0.119	23	0.109	37	0.115	51	0.112
10	0.103	24	0.109	38	0.102	52	0.115
11	0.117	25	0.109	39	0.073	53	0.106
12	0.125	26	0.095	40	0.109	54	0.129
13	0.116	27	0.092	41	0.100	55	0.120
14	0.120	28	0.151	42	0.098		

Average Weight of sound Seed = 0.1104 grams.

Loss in weight per seed. — The average weight of 55 sound Assili cotton seeds was found to be 0.1104 grammes (Table XII). Table XIII shows the weights of seeds which have been injured by the pink bollworm, compared in each case with the average weight of a sound seed.

In column 2 the weights are for a single injured seed from an attacked boll, this seed being the only one attacked out of all the seeds in that boll. In column 6 the weight of two injured seeds is given, these two being the only ones damaged. In column 8 the weights of these two seeds are given separately. It is believed that in most of the cases recorded in column 1 the bolls (1st picking ripe bolls) had been attacked by one pink bollworm only, but in column 2 it is not unlikely that in a

Table XIII.

Loss in Weight of Cotton Seeds Attacked by the Pink Bollworm.

(Seeds taken from Ripe Bolls of 1st Picking.)

	LOSS IN WEIGHT OF SEED WHEN 1 SEED ONLY PER BOLL IS ATTACKED.			LOSS IN WEIGHT OF SEED WHEN 2 SEEDS PER BOLL ARE ATTACKED.					
1 REF. NUMBER OF SEED.	2 WEIGHT OF THE DAMAGED SEED.	3 LOSS IN WEIGHT IF SEED HAD WEIGHED 0.1104 GRAMS.	4 PER CENT LOSS PER SEED.	5 WEIGHT OF THE 2 DAMAGED SEEDS.	6 LOSS IN WEIGHT IF 2 SEEDS HAD WEIGHED 0.2208 GRAMS.	7 PER CENT LOSS PER 2 SEEDS.	8 WEIGHT OF SEPARATE SEEDS IN COLUMN 6.	9 LOSS IN WEIGHT OF SEPARATE SEEDS ON 0.1104 GRAMS BASIS.	10 PER CENT LOSS PER SINGLE SEED.
	Grams.	Grams.		Grams.	Grams.		Grams.	Grams.	
1	0.048	0.0624	56.3	0.109	0.1118*	50.6	0.050	0.0604	54.7
2	0.067	0.0434	39.3	0.073	0.1478*	66.9	0.059	0.0514	46.5
3	0.085	0.0254	23.0	0.115	0.1058*	47.9	0.039	0.0714	64.6
4	0.066	0.0444	40.2	0.159	0.0618	27.9	0.034	0.0764	69.2
5	0.052	0.0584	52.8	0.104	0.1168*	52.8	0.063	0.0474	42.9
6	0.061	0.0494	44.7	0.071	0.1498*	67.8	0.052	0.0584	52.8
7	0.081	0.0294	26.6	0.147	0.0738	33.4	0.072	0.0384	34.7
8	0.030	0.0804	72.8	0.125	0.0958*	43.3	0.087	0.0234	21.1
9	0.060	0.0504	45.6	0.128	0.0928*	42.0	0.029	0.0814	73.7
10	0.081	0.0294	26.6	0.148	0.0728	32.9	0.075	0.0354	32.0
11	0.074	0.0364	32.9	0.160	0.0608	27.5	0.043	0.0674	61.0
12	0.075	0.0354	32.6	0.137	0.0838	37.9	0.028	0.0824	74.6
13	0.079	0.0134	12.1	0.176	0.0448	20.2	0.073	0.0374	33.8
14	0.046	0.0644	58.3	0.095	0.1258*	56.9	0.074	0.0364	32.9
15	0.087	0.0234	21.1	0.145	0.0758	34.3	0.051	0.0594	53.8
16	0.060	0.0504	45.6	0.152	0.0688	31.1	0.074	0.0364	32.9
17	0.058	0.0524	47.4	0.159	0.0618	27.9	0.046	0.0644	58.3

18	0.066	0.0444	40.2
19	0.092	0.0184	16.6
20	0.088	0.0224	20.2
21	0.067	0.0434	39.3
22	0.087	0.0234	21.1
23	0.040	0.0704	63.7
24	0.080	0.0304	27.5
25	0.050	0.0604	54.7
26	0.051	0.0594	53.8
27	0.097	0.0134	12.1
28	0.058	0.0524	47.4
29	0.044	0.0664	60.1
30	0.068	0.0424	38.4
31	0.053	0.0574	52.0
32	0.091	0.0194	17.5
33	0.080	0.0304	27.5
34	0.088	0.0224	20.2
35	0.042	0.0684	61.9
36	0.062	0.0484	43.8
37	0.075	0.0354	32.6
38	0.067	0.0434	39.3
TOTALS ..2.556		1.6212	»
Average = 0.0672 grams.		Average = 0.0426 grams.	38.5 %

0.105	0.1158*	52.4
0.122	0.0988*	44.7
0.162	0.0588	26.6
0.128	0.0928*	42.0
0.119	0.1018*	46.1
2.839	2.0186	»
Average = 0.129 grams.	Average = 0.0917 grams.	41.5 %

* In cases where the loss in weight is more than the average weight of a single sound seed, it is not improbable that two bollworms had been at work in the boll.

0.082	0.0284	25.7
0.052	0.0584	52.8
0.096	0.0144	13.0
0.066	0.0444	40.2
0.094	0.0164	14.8
0.052	0.0584	52.8
0.085	0.0254	23.0
0.071	0.0394	35.6
0.105	0.0054	4.8
0.007	0.1034	93.6
0.088	0.0224	20.2
0.071	0.0394	35.6
0.074	0.0364	32.9
0.082	0.0284	25.7
0.070	0.0404	36.5
0.075	0.0354	32.0
0.084	0.0264	23.9
0.059	0.0514	46.5
0.046	0.0644	58.3
0.063	0.0474	42.9
0.059	0.0514	46.5
0.078	0.0324	29.3
0.084	0.0264	23.9
0.069	0.0414	37.5
0.059	0.0514	46.5
0.064	0.0464	42.0
0.055	0.0554	50.1
2.839	2.0186	»
Average = 0.0645 grams.	Average = 0.0458 grams.	41.5 %

Table XIV.

Results of the Examination of the Ripe Bolls of the 1st and 2nd Picking from 204 Assili Cotton Plants, 1914.

FIRST PICKING.

1 NUMBER OF PLANTS EXAMINED.	2 TOTAL NUMBER OF BOLLS PRODUCED BY (1).	3 NUMBER OF SOUND BOLLS.	4 NUMBER OF BOLLS ATTACKED BY PINK BOLLWORM.	5 TOTAL NUMBER OF BOLLS GIVING PICKABLE FIBRE IN 3 LOCKS.	6 NUMBER OF BOLLS SLIGHTLY INJURED *PRACTICALLY SOUND*.	7 NUMBER SOUND LOCKS SEED-COTTON IN ATTACKED BOLLS.	8 NUMBER SLIGHTLY INJURED LOCKS SEED-COTTON IN ATTACKED BOLLS.	9 NUMBER BADLY INJURED LOCKS SEED-COTTON IN ATTACKED BOLLS (*UNPICKABLE*).	10 TOTAL NUMBER OF SEEDS FROM (2).	11 NUMBER OF SOUND SEEDS FROM (2).	12 NUMBER OF ATTACKED SEEDS FROM (2).
204 from 102 "Nogras".	3,060 = 15 bolls per plant.	1,338 = **43.72 %** of (2).	1,722 = **56.28 %** of (2).	1,658 = **54.18 %** of (2).	320 = **10.46 %** of (2). This total is included in (4) and (5).	722 = 240 2/3 bolls.	829 = 276 1/3 bolls.	2,662 = 885 bolls.	43,843 = 14.3 seeds per boll.	34,292 weight = 3,814.55 grams. Average per sound seed = 0.1112 grams.	9,551 weight = 554.45 grams. Average per attacked seed = 0.058 grams.

SECOND PICKING.

48 from 24 "Nogras".	325 = 6.77 bolls per plant.	22 = **6.8 %** of (2).	303 = **93.2 %** of (2).	30 = **9.2 %** of (2).	8 = **2.4 %** of (2).	52 = 17 1/3 bolls.	179 = 59 2/3 bolls.	654 = 218 bolls.	4,192 = 13 seeds per boll.	1 527 weight 134.98 grams. Average per seed = 0.0883 grams.	2,665 weight = 137.82 grams. Average per attacked seed = 0.0517 grams.

number of the bolls two larvæ had fed. It appears that a seed injured by a pink bollworm losses on the average about 40 per cent of its weight : this figure will of course differ according to the number of seeds attacked by a larva, some will hardly be eaten at all; in others the half or more of the contents will be devoured. The same holds good in the case of teel seed for, although four or five seeds are attacked, the average loss in weight on the total weight of the injured seeds is 37.95 per cent (see Table XXV, page 106).

Loss in yield per feddan. — Table XIV shows the result of the examination of the ripe bolls of the first picking taken from 204 plants in 102 « nogras » or holes (two plants are grown in each hole or « nogra ») on the 12th of September, 1914, from the Society's Farm at Bahtim. The field was divided up into nine plots and from plots 1 to 6 twelve « nogras » of two plants and from plots 7 to 9 ten nogras were taken at equal distances across the field along the middle line of the plot. From each two plants all the bolls — ripe and green — were cut off and placed in a bag. Subsequently the ripe bolls were sorted out into sound and attacked bolls and the seed and fibre from each two plants was weighed and the number of sound seeds noted, etc. The second picking was dealt with in the same way, but it was possible to handle the plants from two plots only (Nos. 1 and 3) with the labour available at the time. The totals of these figures are recorded in Table XIV and from them we are able to calculate approximately the loss per feddan caused by the pink bollworm, assuming of course that the plants examined were representative of the whole area.

At Bahtim the sowing distance apart on the ridge and the distance between the ridges is such as to give a maximum of 13,000 nogras or holes and 26,000 plants per feddan (about 1 acre). However, to obtain this number the land would have to be set out with great exactitude, no space being allowed for irrigation channels and each hole would have to contain two plants, but in practice one plant in a hole sometimes dies from some cause or another after thinning has been carried out. For these reasons we have taken 12,000 nogras or 24,000 plants per feddan for the purpose of our calculation.

Table XV.

Total Weight of Produce from the 204 Plants Examined in Table XIV.

PICKING.	TOTAL WEIGHT OF SEED-COTTON.	TOTAL WEIGHT OF PICKABLE FIBRE.	TOTAL WEIGHT OF SOUND SEED.	TOTAL WEIGHT OF BADLY INJURED FIBRE (*UNPICKABLE*).	TOTAL WEIGHT OF INJURED SEED.
FIRST PICKING.	6,598 grams.	1,786 grams. **27.06 %**	3,814.55 grams. **57.81 %**	443 grams. **6.71 %**	554.45 grams. **8.44 %**
SECOND PICKING.	423.55 grams.	69.3 grams. **16.35 %**	134.98 grams. **31.87 %**	81.45 grams. **19.23 %**	137.82 grams. **32.55 %**
FIRST AND SECOND PICKINGS.	7,021.55 grams.	1,855.3 grams. **26.42 %**	3,949.53 grams. **56.25 %**	524.45 grams. **7.47 %**	692.27 grams. **9.85 %**

Table XV[a].

Number of Ripe Bolls containing Locks of Fibre so badly injured as to be unpickable.

PICKING.	1 NUMBER OF PLANTS.	2 TOTAL NUMBER OF ATTACKED BOLLS ON (1).	3 TOTAL NUMBER OF SOUND BOLLS ON (1).	4 TOTAL NUMBER OF ATTACKED AND SOUND BOLLS ON (1)	5 NUMBER OF BOLLS SLIGHTLY ATTACKED, ALL 3 LOCKS PICKABLE.	6 NUMBER OF BOLLS WITH 1 LOCK OF FIBRE NOT PICKABLE.	7 NUMBER OF BOLLS WITH 2 LOCKS OF FIBRE NOT PICKABLE.	8 NUMBER OF BOLLS WITH 3 LOCKS OF FIBRE NOT PICKABLE.
FIRST PICKING.	204 = 102 nogras.	1,722	1,338	3,060	484 **= 28.1 %** of (2) **= 15.8 %** of (4).	393 **= 22.8 %** of (2) **= 12.8 %** of (4).	272 **= 15.8 %** of (2) **= 8.9 %** of (4).	573 **= 33.3 %** of (2) **= 18.7 %** of (4).
SECOND PICKING.	48 = 24 nogras.	303	22	325	23 **= 7.6 %** of (2) **= 7 %** of (4).	53 **= 17.5 %** of (2) **= 16.3 %** of (4).	80 **= 26.4 %** of (2) **= 24.6 %** of (4).	147 **= 48.5 %** of (2) **= 45.2 %** of (4).
FIRST AND SECOND PICKINGS.	252 = 126 nogras.	2,025	1,360	3,385	507 **= 25.1 %** of (2) **= 15 %** of (4).	446 **= 22 %** of (2) **= 13.2 %** of (4).	352 **= 17.4 %** of (2) **= 10.4 %** of (4).	720 **= 35.5 %** of (2) **= 21.2 %** of (4).

Note. Compare this Table with Table XVII : — shows comparative injury 1914 and 1913.

Table XVI.

State of the Green or Unripe Bolls from Plants.

Examined in Table XIV.

DATE WHEN EXAMINED.	NUMBER OF PLANTS.	TOTAL NUMBER OF GREEN BOLLS.	NUMBER OF SOUND GREEN BOLLS.	PER CENT OF TOTAL.	NUMBER OF ATTACKED GREEN BOLLS.	PER CENT OF TOTAL.
1914. September 12th at time of 1st Picking.....	204	1,727	300	18	1,427	82
October 5th at time of 2nd Picking.....	48	50	0	0	50	100

Note. Compare this Table with Table XVII : — shows comparative injury 1914 and 1913.

To calculate the loss in yield, the first step is to estimate what the probable crop would have been, supposing that none of the bolls produced and which were on the plants at the time of the first and second pickings, had been attacked by bollworms :—

First picking.

From 204 plants 3,060 ripe bolls were produced;
on 24,000 plants 360,000 ripe bolls would be produced.

The average weight of seed-cotton per sound boll of the first picking was 2.522 grammes.

360,000 × 2.522 grammes = 907,920 grammes or
6.4 Kantars per feddan.

Second picking.

48 plants produced in the second picking 325 ripe bolls;
on 24,000 plants 162,500 ripe bolls would be produced.

This number × 2.522 (*the weight of the sound seed-cotton produced by an average sound boll*) *gives* 409,825 grammes or
2.89 Kantars per feddan.

Supposing then there had been no bollworm attack, the 1st and 2nd pickings together should have given :—

9.29 Kantars per feddan.

Actually only a total of 5.11 kantars per feddan was taken for the two pickings.

The difference between this figure and our estimate of what the crop should have been is *4.18 kantars :* — This is the loss per feddan due to the pink bollworm and also to a very much less extent the work of the ordinary bollworm *Earias insulana*.

We will now calculate the yield per feddan using our detailed figures and see how near the result is to the average yield per feddan actually picked, and then by subtracting it from the possible crop figure arrive at the loss. As will be seen, the figure is almost the same as given by the simple calculation made above.

First picking.

1. *Sound bolls.*

From 204 plants 1,338 perfectly sound bolls were obtained;
on 24,000 plants 157,411.7 sound bolls would be produced
157,411.7 × 2.522 (*average weight of seed-cotton per sound boll*)
= 396,992.3 grammes or
2.8 Kantars.

2. *Bolls very slightly attacked.*

From 204 plants 320 bolls very slightly attacked were obtained;
on 24,000 plants 37,647 bolls would be produced :
37,647 × 2.3 (*weight of seed-cotton estimated to be produced by a boll very slightly injured*)
= 86,588.1 grammes or
0.61 Kantars per feddan.

3. *Sound locks of seed-cotton in attacked bolls.*

From 204 plants 722 locks of sound fibre and seed were obtained from the attacked bolls :—

722 locks are equivalent to 241 bolls

204 plants gave 241 bolls.

24,000 plants would give 28,353 bolls.

28,353 × 2.261 (*average weight of a lock of sound fibre and seed in an attacked boll was 0.7539, this × 3 gives 2.261*)

= 64,104.1 grammes or

0.45 Kantars per feddan.

4. *Slightly attacked locks of pickable fibre in attacked bolls.*

From 204 plants 829 locks of such fibre were produced.

This is equivalent to 276 bolls of 3 locks each.

24,000 plants would give 32,470 bolls.

32,470 × 2.0502 grammes (*average weight of a slightly attacked lock in an attacked boll was 0.6834 grammes*).

= 66,569.9 grammes or

0.47 Kantars per feddan.

Adding together these separate items :—

1	2.80	Kantars.
2	0.61	—
3	0.45	—
4	0.47	—
	4.33	Kantars.

we get 4.33 kantars of seed-cotton per feddan for the first picking.

This figure is very close indeed to what was actually picked, namely 4.46 kantars per feddan and so we consider that the plants examined were fairly representive of the whole area.

Loss on the 1st picking. — According to our calculation the 1st picking should have given 6.4 kantars, so apparently the loss was

$6.4 - 4.33 = 2.07$ kantars or a loss in weight of 32.3 % of the possible crop.

Second picking.

Dealing with the second picking in the same manner we get :—

1. *Sound bolls.*

From 48 plants 22 sound bolls were obtained;

from 24,000 plants, 11,000 bolls would be obtained :

$11{,}000 \times 2.522 = 27{,}742$ grammes or

0.196 Kantars per feddan.

2. *Very slightly attacked bolls.*

From 48 plants 8 very slightly attacked bolls were obtained;

from 24,000 plants, 4,000 such bolls would be obtained :

$4{,}000 \times 2.3 = 9{,}200$ grammes or

0.065 Kantars per feddan.

3. *Sound locks of seed-cotton in attacked bolls.*

From 48 plants 52 sound locks of seed-cotton were obtained from the attacked bolls.

52 locks = 17 bolls.

from 24,000 plants 8,500 bolls would be obtained;

$8{,}500$ bolls $\times 2.261 = 19{,}218.5$ grammes or

0.135 Kantars per feddan.

4. *Slightly attacked locks of seed-cotton in attacked bolls.*

From 48 plants 179 locks of slightly damaged seed-cotton were obtained.

179 locks = say 60 bolls.

from 24,000 plants 30,000 bolls would be obtained;

30,000 × 2.0502 = 61,506 grammes or

0.434 Kantars per feddan.

Adding these four figures :—

1	0.196	Kantars.
2	0.065	—
3	0.135	—
4	0.434	—
	0.830	Kantars.

we get 0.830 kantars per feddan, as against 0.65 kantars actually picked over the whole field. Our higher figure can be accounted for partly by the fact that no doubt we picked out cotton from the damaged bolls that would not have been picked under field conditions; and secondly, in our second picking there were a certain number of bolls really belonging to the first picking in which fibre had been left by the «pickers» and which was gathered by us when we cut off all the bolls off the 48 plants at the time of the second picking.

According to our calculation the second picking should have given 2.89 kantars so apparently the loss was :—

2.89 − 0.83 = 2.06 kantars or 71.2 %.

Adding the first and second pickings we get

5.16 Kantars

as against 5.11 kantars actually picked per feddan from the whole area — a very close result.

According to our calculation the crop, if it had not been damaged by bollworms, would have given 9.29 kantars, so the total loss in yield was :—

9.29 − 5.16 =

4.13 Kantars per feddan.

This is equivalent to a loss in weight of 44.45 % of the possible crop.

Even this enormous loss might be added to, because no account has been taken of the small bolls the growth of which is arrested owing to their being attacked by the pink bollworm. Many of these fall off the plants to the ground. Furthermore, owing to the work of the pest no third picking was given by the plants either in 1914 or in 1913.

The same figure for the loss per feddan, viz. : 4.13 kantars, can of course be obtained by basing the calculation on the difference in weight of the produce from the sound and attacked bolls. As one should expect, nearly the whole of the loss arises from the bolls so badly injured that no seed-cotton is obtained from them. This latter figure is as follows :—

First picking.

On 204 plants there were 885 bolls giving no pickable seed-cotton;
on 24,000 plants there would be 104,117.6 bolls;

104,117.6 × 2.522 (*weight of seed-cotton from a sound boll*)
= 262,584.587 grammes or
1.85 Kantars per feddan.

Second picking.

On 48 plants there were 218 bolls giving no pickable seed-cotton;
on 24,000 there would be 109,000 such bolls;
109,000 × 2.522 = 274,898 grammes or
1.9 Kantars per feddan.

1st and 2nd picking loss on above bolls = 3.75 kantars = 90.7 per cent of the total estimated loss of 4.13 kantars per feddan.

THE SHARE OF *EARIAS INSULANA* IN THE LOSS OF 1914.

In 1914 the examination of the bolls from the 252 plants showed that there was about 1 ordinary bollworm, *Earias insulana*, to 36.5 pink bollworms (*Gelechia gossypiella*).

The total number of the larvæ of these two species found in all the

bolls from the above number of plants was 1,877; of this number 1,827 or 97 % were pink bollworms and 50 or 3 % were *E. insulana*.

Allowing 3 % of the damage to have been caused by *Earias*, we get the following loss figures for the two species :—

In 1914, total loss = 4.13 kantars per feddan.

1st and 2nd pickings. { Pink Bollworm's share = 4.0061 Kantars per feddan,
Earias insulana share = 0.1239 Kantars per feddan.

VALUE OF THE COTTON DESTROYED IN 1914.

In 1914, the average price obtained per kantar for the first and second picking was L. Eg. $2\frac{1}{2}$ (Lst. 2. 11 s. $3\frac{1}{4}$ d.).

The loss per feddan of seed-cotton was 4.13 kantars.

The value of this amount at the above price is L. Eg. $10\frac{325}{1000}$ (Lst. 10. 11 s. $9\frac{1}{2}$ d.).

Of this sum

97 per cent or L. Eg. $10\frac{15}{1000}$ (Lst. 10. 5 s. $5\frac{1}{4}$ d.) is the share of the pink bollworm in the loss, and 3 per cent or P.T. 31 (6 s. $4\frac{1}{4}$ d.) is the share of the *Earias* bollworm in the loss.

LOSS ON THE 1913 CROP.

In 1913 a somewhat similar calculation was made for the cotton crop at Bahtim, but the data on which it was based were neither so full nor so exact as in 1914, the result being that there is a very considerable difference in the weight of the crop as estimated from our figures and that actually picked per feddan.

In this case the plants, 115 in number, were taken in a single line across the field and thus are not so likely to have been representative of the whole as those taken in 1914. Moreover, the plants were not removed until after the second picking had been taken and thus we only had the empty boll-shells as a guide to tell us whether or not the boll had been attacked, or in other cases the presence of the locks of damaged fibre left in the bolls as unpickable. The latter are of course of great importance

Table XVII.

Results of Examination of the Ripe Bolls of the 1st and 2nd Picking from 115 Plants of Assili Cotton, Society's Farm, Bahtim. October 25th 1913.

Total number of plants examined.	Total number of ripe bolls produced in 1st and 2nd pickings.	Total number of boll shells free from sign of attack and all fibre picked.	Per cent of total.	Empty boll shells showing sign of attack but from which all fibre had been picked.			Total number of empty boll shells showing sign of attack.	Per cent of total.	Partially empty boll shells damaged locks still containing fibre.		Total number of empty shells containing unpicked damaged fibre.	Per cent of total.	Total number of badly injured bolls from which no fibre was picked.	Per cent of total.
				Shell pierced in one lock.	Shell pierced in two locks.	Shell pierced in three locks.			Containing one lock of fibre unpicked.	Containing two locks of fibre unpicked.				
115	4,450 = 38 bolls per plant.	2,205	49	474 = 10.6 % of Total Bolls	9 = 0.20 % of Total Bolls	1 = 0.022 % of Total Bolls	484	11	402 = 9 % of Total Bolls	141 = 3 % of Total Bolls	543	12	1,218	28

Green Bolls. Examined September 16, 1913. Total.... 200 { 130 sound = 65 %. / 70 attacked = 35 %.

Green Bolls. Examined October 25, 1913. Total.... 591 { 44 sound = 7.44 %. / 547 attacked = 92.56 %.

as from them alone it is possible to get directly a close idea of the loss that was caused.

Table XVII shows the results recorded from the examination of the boll-shells, etc., of the 115 plants of Assili cotton taken at Bahtim October 26th 1913, and from these figures a possible crop and loss calculation has been made out, using the same «boll weights» as for 1914 crop.

One thing is noticeable, viz. that the number of bolls produced per plant was much greater in 1913 than in 1914. Possibly the weights of these bolls may have been rather less in 1913, owing to the bolls per plant being more numerous; if this were the case it would help to explain the difference between our figures and the actual crop figures.

Possible crop, Bahtim, 1913.

On 115 plants 4,450 ripe bolls were produced in the first and second pickings;

on 24,000 plants 928,695 bolls would be produced;

$928{,}695 \times 2.522 = 2{,}342{,}168.79$ grammes of seed-cotton or

16.54 Kantars per feddan,

supposing there had been no loss from bollworms.

The figure is not so extraordinarily high when one considers that the Bahtim Farm has 10 kantar cotton soil, and that in Kalubia 12 kantars per feddan is by no means an unknown yield to be picked per feddan.

The average yield per feddan picked in 1913 was 8.95 kantars from an area of 11 feddans.

16.54 kantars – 8.95 kantars gives us a loss of 7.59 kantars per feddan.

This figure is probably very much too high.

From the date in Table XVII we will now work out the loss in a similar way to the 1914 crop.

1913-1ST AND 2ND PICKING.

Sound bolls.

115 plants produced 2,205 sound ripe bolls;

24,000 plants would produce 460,173.9 bolls;

460,173.9 × 2.522 (*weight of sound seed-cotton per boll*)

= 1,160,558.575 grammes per feddan or

8.2 Kantars per feddan.

Attacked bolls.

1. *Bolls slightly attacked :*— Shells had been pierced but all fibre had been picked.

From 115 plants 484 ripe bolls were obtained, which had been slightly injured;

24,000 plants would give 101,008 such bolls.

101,008 × 2.3 (*weight of seed-cotton from slightly attacked bolls*)

= 232,318.4 grammes or

1.6 Kantars per feddan.

2. *Bolls more severely attacked but giving sound locks of seed-cotton.*

From 115 plants 945 such locks of seed-cotton were obtained. This is equivalent to 315 whole bolls each containing 3 such locks of fibre and seed.

24,000 plants would give 65,739 similar bolls;

65,739 × 2.261 (*weight of sound locks of seed-cotton from attacked bolls*)

= 148,635.879 grammes or

1.05 Kantars per feddan.

Adding these separate items :—

1	8.2	Kantars.
2	1.6	—
3	1.05	—
	10.85	Kantars.

we get 10.85 kantars per feddan.

The actual yield was 8.95 kantars per feddan. Our figure is thus 1.9 kantars too high — a big difference.

Loss per Feddan 1st and 2nd Pickings.

On the other hand, subtracting 10.85 kantars from the possible crop figure of 16.54 kantars we get a loss of 5.69 or a loss in weight of 34.4 per cent of the possible crop.

This loss figure is probably not so far out, as can be demonstrated by basing the calculation on the number of bolls from which no fibre was picked and the locks of damaged seed-cotton left in the partially cleaned bolls.

Bolls giving no seed-cotton.

On 115 plants there were 1,218 attacked bolls from which no seed-cotton was picked.

on 24,000 there would be 254,191.3 bolls;
254,191.3 × 2.522 (*weight of seed-cotton in a sound boll*)
= 641,070.458 grammes or a loss of
4.52 Kantars per feddan.

In 543 bolls on 115 plants there were left a total of 684 locks of badly injured seed-cotton. This is equivalent to 228 bolls each containing 3 locks of unpickable seed-cotton;

In 24,000 plants there would be 47,582.6 bolls;
47,582.6 × 2.522 (*weight of produce of a sound boll*)
= 120,003.317 grammes per feddan or a loss of
0.85 Kantars per feddan.

Adding the two results together :—

4.52 Kantars.
0.85 —
5.37 Kantars.

we get 5.37 kantars per feddan as the loss figure.

This is practically the same as the last figure for the loss viz. :— 5.69 kantars per feddan.

This result must be closely approximate to the amount of cotton actually destroyed by the pink bollworm, *supposing* the plants taken were representative of the whole area and also that 2.522 grammes the average weight of the seed-cotton from a sound boll is not too high a figure for the 1913 bolls, which were numerous.

It is of interest to note that if 11,000 «nogras» or 22,000 plants is used for this calculation the yield as calculated from Table XVII agrees very closely with the yield actually picked. The loss figure then comes to 4.7 kantars per feddan for the two pickings, a loss of 34 per cent.

Neither in 1913 nor 1914 was there a third picking owing to the ravages of the pink bollworm.

Although the loss in 1913 appears higher, it is really lower by some 10 per cent than in 1914. It appears higher because in 1913 the plants gave a very much better yield than in 1914 leaving aside all question of the pink bollworm.

THE SHARE OF *EARIAS INSULANA* IN THE LOSS OF 1913.

From all the bolls and squares obtained in 1913 from the 115 plants examined a total of 2,281 *Gelechia* and *Earias* larvæ were obtained.

Of this number

2,147 were pink bollworms and
134 were *E. insulana*

that is to say, for each *Earias* bollworm there were 16 pink bollworms present or, in other words, 6 per cent of the total were *Earias* and 94 per cent *Gelechia* larvæ.

Applying these figures to the loss figures of 5.69 kantars we get

94 % as the pink bollworm's share in the loss =
5.34 kantars per feddan

6 % as the *Earias* bollworm's share in the loss =
0.35 kantars per feddan.

VALUE OF THE COTTON DESTROYED IN 1913.

In 1913 the average price obtained per kantar for the cotton of the first and second picking grown on the Society's Farm, Bahtim, was L.Eg. 4 (Lst. 4. 2 s. 0 $\frac{1}{2}$ d.).

The loss per feddan of seed-cotton in 1913 was 5.69 kantars.

The value of this amount at the above price per kantar is L.Eg. 22 $\frac{760}{1000}$ (Lst. 23. 6 s. 10 $\frac{1}{2}$ d.).

Of this sum

94 % or L.Eg. 21 $\frac{394}{1000}$ (Lst. 21. 18 s. 10 $\frac{1}{4}$ d.) is the share of the pink bollworm in the loss,

6 % or L.Eg. 1 $\frac{366}{1000}$ (Lst. 1. 8 s. 0 $\frac{1}{4}$ d.) is the share of the *Earias* bollworm in the loss.

FINANCIAL LOSS TO EGYPT CAUSED BY THE PINK BOLLWORM.

It is not improbable that the attitude of many people after having examined the loss figures for a particular farm given in the preceding section will be one of doubt, for they will ask — and naturally so — if the loss caused by the pink bollworm is so heavy as the figures given would appear to show, why is there not a big difference on the wrong side in the total crop figures for the years 1912 and 1913 for example? In 1912 the attack of the pink bollworm was comparatively slight and in 1913 it was of such magnitude as to give rise to a general outcry in Egypt from all concerned with the cotton crop; yet the crop in the latter year was some 160,000 kantars more than in 1912, the increase in the area planted with cotton being only about 1,200 feddans!

Firstly it must be explained that no claim is made for the Bahtim figures being in any way representative of the loss suffered by Egypt as a whole. Fortunately they are not, since conditions in this particular locality or farm are special, but at the same time not entirely exceptional. The Bahtim Farm being in Kalubia Province has a good cotton soil to start

with, and the farm being chiefly employed as a cattle-breeding centre, the forage crops being fed off, the land is very highly manured indeed. The result of this richness is that the cotton grows very tall and produces great quantities of leaf and wood as well as bolls. These conditions favour the pink bollworm and the attack undoubtedly tends to be very much more severe than in the case of a crop growing on soil of ordinary fertility, on a poor land, or in the north of Lower Egypt, where the plants run on the small side producing less leaf and wood in proportion to the number of bolls borne. Small and medium sized plants seem to get more sun and air, and these influences appear to bring about early ripening of the bolls and lessened injury from bollworm. Perhaps also, the moths tend to congregate amongst cotton of dense growth.

On the other hand, the Bahtim Farm is not entirely exceptional for there are many other farms both in Kalubia, Menoufia and other parts of the Delta which in a good year produce from 8 to 10 kantars of cotton and occasionally a much heavier crop than this even. On such farms the injury from pink bollworm has, as we know from reports, been exceptionally high *.

However taking the two years 1912 and 1913 it seems evident in face of the official crop figures that there must have been a tendency on the part of the growers to exaggerate their losses, since in many cases they said they had only picked one half, or even less, of the quantity of cotton they were accustomed to take from their land. If this had really been the case at all generally over Egypt it could only have had one result one would think, viz. that the total crop figure for 1913 would have shown a great diminution compared with that of 1912. This as we know was not the case. If the growers had said we only picked

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* As two cases out of many that have come to my notice I may quote the following.

A owning very rich land in Gharbia. Before the pink bollworm he used to get 12 kantars per feddan. In 1914 he took 6 kantars, and in 1915 $4\frac{3}{4}$ from the same estate.

B owning very rich land in Dakahlia. Before the pink bollworm he was accustomed to expect 8 kantars yield per feddan. In 1914 he picked 5 kantars and in 1915 $2\frac{1}{2}$ kantars per feddan from the land that used to give 8 kantars.

one half of what at one time our crops promised to give they would have in all probability been very much nearer the truth, and it is on these lines that the loss from the pink bollworm attack must be regarded. No doubt in many cases only one half the crop of 1912 was taken in 1913, but these may have been, generally speaking, exceptions or local occurrencies, because the severity of the pink bollworm attack is by no means uniform over the whole country, or in a province nor even in quite a small district. In this the pink bollworm is like other insect pests the attacks of which nearly always vary very considerably in intensity not only in different localities, but in different parts of the same district.

As already stated, in the opinion of the writer, the explanation of the larger crop in 1913 in spite of the undoubted severity of the pink bollworm attack, lies in the fact that the plants produced sufficient bolls to have given in the neighbourhood of a ten million kantar crop, and thus notwithstanding the enormous number of bolls destroyed and partially destroyed the number which escaped injury was sufficient to give a big crop and thus to a large extent mask the ravages of the pest*.

Another factor of great importance is that in 1913 the ordinary bollworm *Earias insulana* was comparatively scarce and caused much less harm than usual. This balanced as it were a great deal of the increased injury by the pink bollworm.

Again, it is possible that in spite of a low Nile the crop in Upper Egypt was heavier than in 1912. If this was the case it would help to balance increased damage in Lower Egypt. In Upper Egypt there can be no doubt that the attack was much less severe than in the Delta.

Another point worthy of consideration as regards the work of the pink bollworm is the question of the probable relationship between the

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* Since this was written a somewhat novel aspect of the case has come to the knowledge of the writer. This is that in 1914 and 1915 the village authorities have stated the area of cotton planted within their jurisdiction to be considerably less than it really is, their idea or hope being that the estimate of the total crop shall be lowered, and in consequence the market price per kantar raised to their advantage. That this has occurred in

prevailing meteorological conditions and the amount and severity of the damage inflicted on the cotton crop by this pest. A favourable spell of ripening weather in the latter part of September and the first fortnight of October is likely to make a very big difference indeed to the crop owing to the number of bolls ripening off and opening quickly and which will thus be saved or partially saved from damage. On the other hand, cool days and cold nights at this time of the year will tend to retard the ripening of the bolls, which remaining in a green juicy state for a longer time stand a much greater chance of being attacked, and moreover, they will suffer greater damage if invaded; consequently the crop is likely to be considerably reduced.

Comparing the crops of 1913 and 1914 we find a very big difference. In 1913 the crop was 7,663,800 kantars from 1,723,094 feddans*; in 1914 it was, as at present estimated, about 6,344,349 kantars from 1,755,270 feddans of land. Thus in spite of an increase of 32,176 feddans under cotton there was a reduction in the crop of about 1 million 319,451 kantars. In 1914 the value of this crop would have been roughly about two million six hundred thousand pounds sterling.

In my opinion the pink bollworm may well have accounted for this loss and a good deal more besides. In fact unless the losses experienced at Bahtim and in the surrounding district, and the reports and samples of bolls received from all parts of Egypt were entirely exceptional and misleading, which could hardly have been the case, the damage both in 1913 and 1914 must have been very heavy indeed. At a rough estimate I should put the loss at from about 1 to perhaps as much as 1 $\frac{1}{2}$ kantars per feddan taking the country as a whole. Now let us see how such a loss works out in quantity and value.

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some places seems certain, but how generally is *entirely another matter*. If this practice was common it would effect considerably the figure for the average yield per feddan as given for 1914 and estimated for the current year 1915. Both figures are in the opinion of a great number of growers too high in view of the enormous damage done by the bollworm.

* The crop in 1912 was 7,499,100 kantars from 1,721,815 feddans.

In 1913 1,723,094 feddans were planted with cotton. The crop picked from this area was 7,663,800 kantars.

Now if 1 kantar of cotton was destroyed by the pink bollworm, there would have been — supposing no injury to have occurred from bollworm and leaving aside other considerations affecting the crop — an addition to the crop actually picked, of 1,723,094 kantars, making a possible crop in 1913 of 9,386,894 kantars. The above loss figure thus represents a loss of 18.3 per cent or 22.4 per cent of the crop according to whether the calculation is based on the estimated possible crop or the amount of the crop actually picked.

Taking the loss at $1\frac{1}{2}$ kantars per feddan there would be a loss of 2,584,641 kantars. This would have given a possible crop of 10,248,441 kantars. Thus the 2,584,641 kantars represents a loss of 25.2 per cent or 33.7 per cent of the crop according to whether the percentage is calculated on the possible crop or that actually picked.

As regards the money value of the cotton destroyed by the bollworms: 1,723,094 kantars at, say — 17 tallaris or dollars (=L. Eg. $3\frac{40}{100}$ or Lst. 3. 9 s. $9\frac{1}{2}$ d.) would be L. Eg. 5,858,419. The loss at $1\frac{1}{2}$ kantars per feddan was equal to 2,584,611 kantars. The money value of this at 17 dollars would be L. Eg. 8,797,774. Both these sums are indeed very large and yet the writer believes that they are not an exaggeration of the loss inflicted by the work of the bollworms. No matter which of the sums is the more correct, either affords ample evidence of the vast importance of the insects pests of the cotton crop and forms ample support for the expenditure of large sums of money in research and experimental work for the purpose of, if not abolishing the pests from our cotton fields, at least of reducing them to such numbers that they shall be incapable of inflicting injury of a serious nature. It should be possible to accomplish the latter.

To continue: in 1914 there were 1,755,270 feddans of cotton. A loss of 1 kantar per feddan on this area means a total loss of 1,755,270 kantars. This sum added to the crop actually picked in 1914, viz. 6,344,349 kantars, gives a possible crop for that year of 8,099,619 kantars. The

loss thus represents 21.6 per cent or 27.6 per cent of the crop according to whether one takes the possible crop or that actually picked.

A loss of 1 ½ kantars per feddan would have totalled 2,632,905 kantars and thus the crop, if there had been no loss from bollworm, might have been 8,977,254 kantars. The loss in this case then is 29.3 per cent or 41.5 per cent of the crop according to whether the calculation is made on the possible crop or the crop actually picked.

The price of cotton in 1914 was very low so the loss does not appear so heavy in 1914 as in 1913 whereas in point of quantity it was greater. Taking the value at L.Eg. 2 per kantar the value of the cotton destroyed by the bollworm at 1 kantar per feddan would be L.Eg. 3,410,540, and at 1 ½ kantars L.Eg. 5,265,810.

With regard to all these figures it must be pointed out that they really include also the injury caused by the ordinary bollworm *Earias insulana*, but we know that in 1913 and 1914 the share of this pest in the loss was insignificant when compared with that of the pink bollworm. A small part of the loss is due also to «mabrum» bolls failing to produce fibre: some of these bolls have not in all cases, so far as one can tell, been attacked by a bollworm. However the loss from this cause is very slight and for practical purposes need not be considered.

It must be remembered also that as regards the high figures for the possible crop, that in past years although there was no pink bollworm there has always been considerable and sometimes very severe injury from other insect pests — chiefly the ordinary bollworm *Earias insulana*. This adverse influence has always helped to keep the actual crop figure below the 8 million kantar line.

Big as the values are of the cotton destroyed by the bollworm in 1913 and 1914, the figures are by no means final and the pink bollworm's liability extends further, since there is the depreciation in quality of the cotton picked to be considered. There can be no doubt that a great deal of the cotton harvested in Lower Egypt more especially, in 1913 and 1914 was of inferior quality as regards the amount of «dead» or «mabrum» cotton present. It may be remarked that in many cases first

picking cotton was, owing to the amount of mabrum cotton present, more like a third picking of the old days before the advent of the pink bollworm and at a time when the ordinary bollworm *Earias insulana* was often responsible for severe injury to the late pickings.

The writer has at present no data on which to suggest any sort of loss figure for the depreciation in value of the crop marketed in 1913 and 1914 consequent on the loss in quality due to the injury caused by the pink bollworm. There can be little doubt, however, that if it could be estimated the amount would be very large.

Again, no figures are available by which an estimate of the value of the indirect losses caused by the pink bollworm might be made. But it will be readily understood that a large sum of money would be involved in handling the extra one or two millions of kantars of cotton which might have been picked had there been no injury from bollworm.

THE RELATION AS REGARDS DESTRUCTIVENESS BETWEEN THE PINK BOLLWORM AND OTHER INSECT PESTS AND DISEASES OF THE COTTON PLANT.

There are several insect pests and one fungoid disease of the cotton plant which may influence the extent of the damage to a crop of cotton caused by the pink bollworm.

Firstly there are the cutworm (*Agrotis ypsilon*, Rott.) and the disease known as «sore-shin» the cause of the «damping-off» of seedling cotton plants. The attacks of these two enemies, especially on early sown cotton, may be so severe that in the northern half of Lower Egypt very large areas of land have to be entirely re-sown, in some cases not once only but twice, or practically so.

Now it is the early sown cotton which, if a successful germination and stand of young plants is obtained, should be the least injured by bollworm, because the tendency will be for the plants to ripen their cotton

early and give a big first picking. It is these first picking bolls that suffer least since they ripen off or at all events grow to a good size, before the pink bollworm has become very numerous. The destruction of the early sown plants and the consequent delay of resowing may result in a serious set back to the crop, which from an early sown one may in the end become a late sown crop. The effect of this check is seen at the end of the season in a delayed and more severely injured first picking — the bolls being late run greater risk of being attacked at a younger stage and consequently suffer greater damage. — It is probable also that a light first picking will be taken owing to many of what should have been first picking bolls not ripening until the time of the second picking.

A bad and late attack of the cotton worm (*Prodenia litura*, Fab.) will have similar results. In late July or early August this pest may destroy large numbers of the flowers and squares that should produce the first picking bolls. Furthermore, early set bolls on the lower branches (on which the first and best bolls are borne) may be destroyed. The effect of this work is visible in the autumn in a retarded first picking which as a result of the delay is likely to be more severely injured by the pink bollworm. Again, the first picking is likely to be a less proportion of the whole crop than is normal owing to the destruction of first picking flowers, squares and young bolls in July and August. The later the bolls the greater is the chance of their being attacked not by a single pink bollworm only but by several : moreover, the younger the boll is when it is invaded the greater will be the results of the injury caused by the pink bollworms.

Two other pests which may cause a set back to the crop in its early stages are the Cotton Aphis (*Aphis gossypii*, Glover.) and the Thrips (*Thrips sp*).

FOOD PLANTS.

In Egypt the known food plants of the pink bollworm are cotton (*Gossypium spp.*); bamia or okra (*Hibiscus esculentus*); teel or hemp (*Hibiscus cannabinus*); and the hollyhock (*Althæa rosea*), a flowering plant grown in gardens.

The pest has not been found in the buds of the ornamental red *Hibiscus* (*Hibiscus rosasinensis*), a plant found in most gardens in Egypt: but two larvæ have been reared to 1/4 growth on this food and the reason they died at this age is believed to have been due more to the buds becoming rotten inside than to the absolute unsuitability of the *Hibiscus* as a food plant. Under natural conditions, however, it is probable that *Hibiscus* has very little attraction for the pink bollworm. In the laboratory the young larvæ show no inclination to enter the buds, and of thirty placed in a glass tube with this food only two entered buds and fed on the contents.

The hollyhock has only recently been recognized as a food plant of the pink bollworm, eggs being found for the first time in 1915 on the green seed capsules and also on the flower buds of this plant in the garden of Mr. H. C. Jefferys at Sakha. The larvæ were raised successfully on this food.

It may be pointed out here that the pink bollworm should not be confused with the larva of a moth known as *Crocidosema plebiana*, Zell., (Plate VII, Fig. 5) which also feeds in the seed capsules and flower buds of the hollyhock.

Other plants that must be looked upon with suspicion as possible host plants of *G. gossypiella* are the weed known as Til Shitani or Devil's Teel, or Qoton Shitani — Devil's Cotton; and Khobbêza (*Malva parviflora*) grown as a vegetable in this country. Both would be of importance, if the pink bollworm can exist on them, as a possible source of early food supply for the pest. The ordinary bollworm (*Earias insulana*) feeds on both plants.

It will be remarked that all the known or suspected food plants of the pink bollworm belong to the same natural order, the *Malvaceæ*: but the species has been recorded by Dudgeon[15] as having been bred by him from pomegranates which belong to an entirely different natural order. This observation needs confirmation and if it should turn out to be accurate, it is of serious import, since it would then seem that the pink bollworm might have a much wider range of food plants than hitherto

suspected. If the pest feeds on a plant so different from cotton as the pomegranate, there seems to be no particular reason why it might not feed also on — say the seed pods of the sunt tree (*Acacia arabica, var. nilotica*)* : and supposing this were the case it would seriously add to the difficulties of control. Fortunately, however, it has not yet been found in sunt pods, although search has been made frequently in them for these larvæ.

As regards other countries, Maxwell-Lefroy[16] states that the wild food plants of the pest «appear to be trees with oily seeds which are widely distributed in India». The natural order or orders of these trees is not mentioned.

Fullaway[17] states that he has bred the species from milo (*Thespesia populnea*). This is a member of the *Malvaceæ*.

LIFE HISTORY OF THE PINK BOLLWORM.

SUMMARY.

The female pink bollworm moth lays her eggs on cotton, teel (*Hibiscus cannabinus*) and bamia (*Hibiscus esculentus*), the food plants of the larvæ. Cotton appears to be the most favoured of the three, followed by teel and lastly bamia. The eggs (minute convex-oval objects, pale at first but subsequently changing to an orange-red colour) may be laid on the under surface of the leaves as well as on the cotton bolls, or on the seed capsules of the other food plants. The eggs hatch in from three to seven days, according to season, giving rise to tiny yellowish and very active larvæ, which may immediately bore into a boll or feed for a short time and in a desultory manner on the leaves during their search for a boll. In the interior of the boll the larva becomes white and finally pink or red in colour. It feeds chiefly on the seeds; of these it injures one, two or perhaps more to a varying degree. The effect of this attack on the boll differs both according to the time of year and the number of larvæ

* The larva of a butterfly, *Virachola livia*, feeds on these two food plants.

which invade it. The damage may be slight or so complete that no cotton is produced. After feeding from two to three weeks the larva reaches maturity when it will have a length of about 12 mm. It now leaves the boll by a more or less circular exit hole cut through the shell and pupates in a light silken cocoon spun in or under some convenient shelter on the ground, such as fallen leaves, dead flowers, lumps of soil, etc.; a few larvæ may occasionally pupate in the interior of either a green or of a ripe boll. The pupal stage lasts from, roughly speaking, ten days to a fortnight and then the adult emerges. After an interval of three or four days the moth, if a female, will be ready to lay eggs again, thus giving rise to a fresh brood. The number of broods per annum is not yet known.

From September onwards many of the larvæ, instead of leaving the bolls to pupate, remain in them spun up in a closely woven cocoon in the interior of a single seed or perhaps two seeds spun together. They remain in the larval stage in this situation until the following April, May, June, July, August, September, October, November and even December or even much longer before changing to the pupal stage and finally giving rise to moths. Some moths may emerge during January, the larva having rested for a short time only or more probably not at all. The principal period of activity, when the resting larvæ change to pupæ, is from the middle of June to the end of September. It appears that occasionally some larvæ, which mature late in the autumn, may pupate and remain in this stage for an exceptionally long time — several months — the moths not emerging before March or April. Generally speaking, however, the winter is passed in the larval stage spun up in cocoons in the seed of dead bolls left on the cotton sticks, and lying on or buried in the ground; also in the seed capsules of teel and bamia. Large numbers are present in the cotton seed used for sowing, having commenced the resting stage previous to the harvesting of the cotton. Resting pink boll-worm may also be looked for in any buildings where seed-cotton or seed has been stored and handled. What happens in the early summer to the moths which emerge before the cotton has any squares, flowers or bolls

on it is not known, but it is thought and hoped that they die without giving rise to offspring. Thus the species must depend for its continuity on the later and continuous summer emergence of moths from the old bolls of the previous crop and the other retreats mentioned above. The pink bollworm attack commences as soon as the flowers or even squares (flower buds) are well formed and increases in severity from then onwards until finally one hundred per cent of the bolls are in many cases invaded by one or several larvæ.

So far we have no evidence to show that the moths can live long periods either during the winter or summer without laying eggs.

In Egypt the species may continue to breed during the winter if food plants are available.

THE EGG STAGE.

Description. — The eggs (Plate IV, Figs. 2 and 3) of the pink bollworm moth are very small, measuring only from 0.52 mm. to 0.54 mm. in length and 0.24 mm. to 0.26 mm. in diameter. Although their form is apt to be a little irregular, the general outline is bluntly oval, but rather more pointed at one end than the other. The upper surface of the egg is slightly convex. The surface is sculptured with a series of longitudinal parallel lines or folds in the shell, which are braced together by a series of obliquely placed transverse striæ alternating as to direction.

When first laid, the eggs are of a pearly white to faintly greenish colour. The shell is highly iridescent. About the second day the colour changes, becoming faintly orange with distinct irregular orange-red spots at the broader end. This colour deepens until the egg becomes of a rich orange colour appearing reddish to the naked eye. It has been observed that in the autumn the red or orange-red colour of the egg appears to be more intense than during the summer. Before hatching, the dark head of the larva is plainly visible and the egg becomes much less brilliant in appearance.

Incubation period. — The following table shows the duration of the

egg stage which lasts from four to five days in June and July to seven or seven and a half days in October. The incubation period varies slightly according to whether the eggs are kept indoors or outside, no doubt the big drop in temperature at night out of doors checks the development of the embryo larva. In the latter part of October and in November this stage lasts as long as ten days or perhaps longer.

Table XVIII.

Duration of the Egg Stage.

EGG LAID NIGHT OF	HATCHED.	DURATION OF EGG STAGE.	REMARKS.
June 9 1913.....	June 14 a.m.....	4 days.	Kept in laboratory.
— 11 —	— 17 a.m.....	5 —	— outside insectary.
— 23 —	— 27 p.m.....	3 1/2 days.	— laboratory.
July 18 1913.....	July 23 p.m.....	4 1/2 —	— outside insectary.
October 14 1913.....	October 23 a.m.....	7 —	— — —
September 22 1914...	September 28 a.m....	5 —	— — —
— 22 — ...	— 28 a.m....	5 —	— laboratory.
— 23 — ...	— 28-29	4-5 —	— —
— 23 — ...	— 30 p.m....	6 1/2 —	— outside insectary.
— 25 — ...	October 1 a.m.....	5 —	— — —
— 26 — ...	— 1 a.m.....	4 —	— laboratory.
— 26 — ...	— 2 a.m.....	5 —	— outside insectary.
— 29 — ...	— 5 p.m.....	5 1/2 —	— laboratory.
— 29 — ...	— 7 a.m.....	7 -	-- outside insectary.
— 30 — ...	— 7 a.m.....	6 —	— laboratory.
— 30 — ...	— 8 a.m.....	7 1/2 —	— outside insectary.

Hatching of the egg. — When ready to emerge the young larva, which can easily be seen curled up head to tail inside the egg, bites its way through the egg-shell, an operation of brief duration, and makes its escape. The egg-shell is left intact as a small white object adhering to the leaf. From laboratory observations it appears that the eggs often hatch very irregularly, a difference of a few to many hours occurring

between the escape of the larvæ from the same batch of eggs. It may be, however, that the eggs had been laid at different times by the same or different moths, which gave rise to these apparent irregularities.

Position of the egg on the plant. — The eggs of the pink bollworm moth may be found on almost any part of the cotton plant, including the bolls, squares, bracteoles, leaves — both the young and old leaves — the axils of the leaves and buds and also the small leaves of the growing points. Generally speaking, the eggs appear to be laid singly; but several may be found on the same leaf or boll; groups of as many as eight to ten ova have been found on the bolls. When laid on the bolls they may be placed in one of the grooves near the tip formed by the juncture of the loculi, or on the shell of the boll, between it and the enveloping involucre; in some cases they may be found as low down as and actually on the calyx. When laid on the leaves the eggs will be found on the under surface. The hairy under-surface of the young leaves appears to be a very favourite situation for oviposition by the female moth; eggs may, however, be found also at almost any point on the lower side of large leaves, and not infrequently in the angles formed at the spot where the main veins spring from the leaf stalk or petiole. The latter position is very often chosen for the eggs, and likewise the axile of a leaf or bud, by moths in captivity.

It is of considerable importance to know the common situation of the eggs, since it indicates what the probable habits of the newly hatched larva will be; and we must know these if we wish to consider the utility of spraying the foliage with some poisonous substance, such as arsenate of lead, to destroy the pest in this early stage. It had been intended to carry out the necessary observations during the past summer, but illness of one of the staff and other circumstances prevented this being done. However, from the ease with which these ova can be found in the field on the leaves, it is believed that a very high proportion are laid in this situation. The following observations were made in November and December of last year (1913) when it was rather late for finding large

numbers of ova, and although the records are too few to be in any way conclusive in the absence of others it is perhaps worth while mentioning them. On twenty five plants a total of 59 eggs was found. These were distributed as follows :—

Table XIX.

Situation of the Egg on the Cotton Plant.

ON SMALL LEAVES AT GROWING POINTS AND ABOUT THE "SQUARES"	ON LARGE LEAVES.	ON SQUARES.	ON BOLLS.	ON BRACTEOLES OF BOLLS AND SQUARES.
37 eggs.	7 eggs.	6 eggs.	7 eggs.	2 eggs.
62.5 %	12 %	10 %	12 %	3.5 %

Number of eggs laid by the female moth. — The number of eggs laid by a female has not yet been worked out in the laboratory, but from the examination of the ovaries of many females it is believed that under natural conditions this species is capable of laying from four to five hundred eggs. This number applies to well developed moths some of which might be capable of laying a still larger number if all the potential eggs in the upper part of the ovarian tubes developed. On the other hand small individuals may only produce about 250 eggs.

THE LARVA STAGE.

DESCRIPTION OF THE DIFFERENT LARVAL STAGES OF THE PINK BOLLWORM.

Owing to the larvæ feeding inside the bolls it is difficult to ascertain the number of moults and the change in form and colour undergone by the larva after each moult and so far we have no precise information on this subject.

Description of the newly hatched larva. — When first hatched the pink bollworm (Plate IV, Fig. 4) is a tiny slender caterpillar just under 1 mm.

long. The body is yellow in colour, and tapers considerably from the first three or thoracic segments towards the posterior or last segments. The head is large, dark brown to almost black, and polished. The thoracic shield is rather indistinct, pale, shiny and very faintly shaded on the posterior margin. The legs are pale and well developed. The most noticeable characteristic about the young larva are the hairs on the body which are slightly dilated at the apex.

The young larva is able to crawl at a very rapid rate.

After feeding for a short time the larva becomes of a shiny milky-white colour. The head is dark brown and the thoracic and anal shields are corneous and of a brown or smoky hue, legs pale, spiracles dark. Hairs pale, not dilated at the apex and moderately long.

When the larva has reached a length of about 6 mm. or rather more, the first faint indications of the pink colouring appear as rosy or pinkish suffusions around the spiracles and hair tubercles. The ground colour of the body at this stage is still yellowish-white and shiny. The head has changed to a chestnut brown and the thoracic shield is brownish.

As growth proceeds so the pinkish colouring becomes more pronounced until the appearance of the full-grown larva is attained.

Description of the full-grown pink bollworm. — The full-grown pink bollworm (Plate IV, Figs. 6 and 7) measures about 10 to 12 mm. long by 2.5 mm. in the middle. In form it is inclined to be flattened and tapers slightly from the middle towards the tail end and also towards the head, which is small.

The pink colouring is slightly variable as regards intensity. The resting larvæ tend to be more of a decided pinkish, rose-pink, or prawn-pink in colour; and the active summer larvæ of a dullish red hue which is lightened by the shiny skin; but the latter also vary very considerably in shade. The head is chestnut brown with the mouth parts dark brown. The thoracic shield is dark brown cleft by a pale median line. The shield on the anal segment is pale brown and very inconspicuous.

The ground colour is yellowish in the case of the resting larvæ and

flesh-coloured to yellowish in the active summer larva. The pink or reddish colour is distributed in broad transverse bars extending over the back to just below and surrounding the small inconspicuous spiracles — which are brown in hue. On each band of colour there is a very fine inconspicuous clear median line and also a transverse clear line towards the posterior margin of the colour belt and two clear submedian obliquely placed linear spots. Between the transverse bands of colour the body is yellowish or flesh-coloured. The venter is pale — yellowish or flesh-coloured; the prolegs are pale; also the thoracic legs with brownish claws.

The hairs on the body are pale and moderately long. The skin is very shiny.

DURATION OF THE LARVAL LIFE.

Some difficulty has been experienced until recently with rearing the pink bollworm. The young larvæ frequently will not enter the bolls provided for them, but wander about in a restless manner and either escape if the tube, etc., containing the boll is not almost hermetically sealed or else they are drowned in the moisture condensing on the glass. Another difficulty has been that when a good supply of young larvæ hatching from the eggs was available, to find bolls not already infested with bollworms to feed them on. If the bolls are already infested by one or perhaps several pink bollworms of different and unknown age, confusion results and breeding records become of doubtful value. The laboratory breeding records for the above reasons are at present not numerous; several of them show that this species may take only from nine to ten days at a fairly constant and high temperature to complete its larval age. This seems to be exceptionally rapid and I am inclined to doubt the validity of these observations, errors perhaps having crept in on account of the bolls having been already invaded by pink bollworms when picked.

A new method has now been adopted which, it is hoped, will enable large numbers of larvæ to be reared with exactness as regards the duration of the larval life and under quite natural conditions.

Maxwell-Lefroy states in «Indian Insect Pests» [18], p. 93 :—

«The larval life varies in duration according to season but occupies two to three weeks during the active period.»

The following Table XX gives the only available records we have at present; several of them agree closely with Lefroy's observations.

Table XX.

Duration of the Larval Stage.

EGG HATCHED AND LARVA ENTERED BOLL.	LARVA LEFT BOLL TO SPIN COCOON.	DURATION OF LARVAL STAGE.	REMARKS.
June 25.....	July 7.....	12 days.	Kept in laboratory, temperature high and constant.
July 10.....	July 20.....	10 —	— —
— 23.....	August 3.....	11 —	— —
— 27.....	— 5.....	9 —	— —
— 27.....	— 6.....	10 —	— —
— 27.....	— 7.....	11 —	— —
— 27.....	— 11.....	15 —	— —
September 6...	September 25..	19 —	Kept in outside insectarium.
— 4...	— 16..	12 —	Kept in laboratory, temperature high and constant.
— 4...	— 19..	15 —	— —
— 4...	— 19..	10 —	— —

Range 9 to 19 days. Average 12 days.

HABITS AND WORK OF THE PINK BOLLWORM.

Habits of the newly hatched larva. — The habits of the newly hatched larva will vary slightly according to whether the eggs have actually been laid on a boll or on some other part of the plant, such as a leaf. In the first case the young pink bollworm is very favourably situated, since it may and often does at once bore into the boll. The entry may be effected at any part of the boll from the base to the apex, not infrequently some point in one of the locular grooves is chosen. At this stage the larva sometimes

exhibits a very interesting habit. In order, we may suppose, to protect itself during the tunnelling operations through the shell of the boll, it spins a small covering of silk under which it performs the work. Whether this tent is always made, we do not know, but are inclined to think that it is not, since what appear to be entrance holes of this larva may be found in the shell of the boll, but no trace of the silken covering.

When once a larva has decided on the spot where to enter, it takes only about twenty minutes or half an hour for it to disappear from view into the boll or the wall of the boll. The entrance hole is very minute and can hardly be seen with the naked eye; it is as a rule surrounded with a small quantity of yellowish dust — the fragments bitten out of the shell of the boll. This tiny wound soon closes up leaving only a very small depressed, but sometimes raised, scar of a brownish colour. Thus a green boll exhibits as a rule no conspicuous external signs to show that it has been invaded by the pink bollworm.

In the second case mentioned — when, for example, the egg is laid on a leaf — the young larva is most unfavourably situated, since it has perhaps to spend a long time and travel a long distance over the plant before it finds a bud, flower or boll into which it can enter. During the whole of these wanderings it is exposed to the attacks of predaceous enemies and also to the heat of the sun, dryness perhaps, as well as actual fatigue. The number of larvæ that perish from one or other of these causes before finding a suitable location is probably large. Newly hatched larvæ can be found on the foliage of the cotton plant, but they always give one the impression of being ill at ease in such an environment and are generally crawling about in a most active and restless manner, presumably in search of a boll. In captivity the first stage larvæ can be kept alive up to three days on young cotton leaves in which they eat minute holes — like pin holes. Some of the larvæ seem to grow a little on this diet, others hardly or not at all, and yet others appear not to take any food but spend all their time wandering about in search of escape and more congenial surroundings. The fact that the larvæ can live on leaves for as long as three days is of importance, since there is no reason to doubt

that they can also do this under natural conditions, thus leaving themselves a very fair margin of time in which to find a boll.

Both Lefroy [19] and Fullaway [20] mention the fact that the first larval stage of this pest feeds on the foliage for a short time before boring into a boll. The Deputy Director of the Cawnpore Experimental Farm [21] says :—

«Like the two previous pests, just at first they do not appear to adopt their boring habits.»

I regard this feeding on the leaves as incidental in the search for a boll rather than a distinct habit of the larvæ of this species, which are most essentially internal feeders.

CHOICE OF DIFFERENT PARTS OF THE COTTON PLANT AS FOOD BY THE PINK BOLLWORM.

The preference shown for any particular part of the cotton plant will naturally depend somewhat on the time of the year; for instance in June there are no bolls on the plants, so the larvæ have perforce to content themselves with squares or flowers. It has already been stated that the young larvæ may incidentally feed on the leaves, but they are not able to grow to any size on these, having to seek other and more suitable quarters as soon as possible. Although the flowers and squares or young flower buds are attacked, the young pink bollworms do not seem at all partial to these parts, thus differing from *Earias insulana* which readily feeds on them.

In October 1913, in two thousand squares only nine or 0.45 per cent contained *Gelechia* larvæ, whereas 100 bolls picked in the same field and at the same period showed that 68 per cent were infested with pink bollworm.

The following Table XXI shows the degree to which the squares, flowers and bolls were infested in 1914 on different dates.

It seems quite natural for the bolls to be preferred as in them the larva finds the oily and nutritious seeds to feed upon.

Table XXI.

Choice of Different Parts of the Cotton Plant as Food by the Pink Bollworm.

DATE of EXAMINATION.	"SQUARES" (FLOWER BUDS).			FLOWERS.			GREEN BOLLS.			RIPE BOLLS. 1st PICKING.			RIPE BOLLS. 2nd PICKING.		
	NUMBER OF SQUARES EXAMINED.	NUMBER ATTACKED BY THE PINK BOLLWORM.	PER CENT.	NUMBER OF FLOWERS EXAMINED.	NUMBER ATTACKED BY THE PINK BOLLWORM.	PER CENT.	NUMBER OF BOLLS EXAMINED.	NUMBER ATTACKED BY THE PINK BOLLWORM.	PER CENT.	NUMBER OF BOLLS EXAMINED.	NUMBER ATTACKED BY THE PINK BOLLWORM.	PER CENT.	NUMBER OF BOLLS EXAMINED.	NUMBER ATTACKED BY THE PINK BOLLWORM.	PER CENT.
1914.															
June 30.....	500	2	0.4	500	1	0.2	None present on plants.						"	"	"
July 23.....	"	"	"	500	1	0.2	500	30	6	"	"	"	"	"	"
August 17...	"	"	"	500	2	0.4	500	55	11	"	"	"	"	"	"
September 12.	56	3	5.35	9	1	11.11	1,727	1,427	82	3,060	1,722	56.28	"	"	"
October 6...	24	2	8.33	0	"	"	50	50	100	"	"	"	325	303	93.2

CHARACTER OF THE INJURY TO SQUARES AND FLOWERS.

The nature of the injury to these parts is of no particular interest. In young squares the tiny bollworms feed on the undeveloped anthers and staminal columns; a square so injured probably dies and falls off. There is one point, however, upon which observations are wanted, namely to determine if squares attacked by this species « flare » or open out and finally fall from the plant as readily as when they are invaded by the young larvæ of *Earias insulana*. Larger squares may proliferate as the result of the attack : the flower in such cases is malformed.

When the square is large, the petals of the future flower being well developed, invasion by the pink bollworm does not affect it; development proceeds and the flower finally opens. Such a flower may to casual observation be perfectly healthy, there being no noticeable holes eaten in the petals. If, however, the staminal column and the anthers are carefully looked at, a spot will be seen where a number of anthers and their pollen appear to have stuck or been spun together (Plate V, Fig. 2). This is the work of the pink bollworm which will be found amongst or under this yellow or brownish mass — the colour depending on the stage the injury has reached. When once the appearance of this form of attack has been seen it is easy to recognize flowers which harbour the pest. Another sign of the presence of a pink bollworm on the staminal column is the presence there of small black specks — the excrement of the larva. After feeding on the stamens and anthers, the bollworm may occasionally bore through the base of the staminal column into the young boll. A pink bollworm can complete its growth in a flower, if the latter was first invaded whilst still in the square stage.

NATURE OF THE INJURY TO THE BOLLS.

One of the most striking peculiarities of the attack of this insect is the way both its presence in the boll and the injurious effect of its work there remain hidden up to the last moment as it were. Generally speaking, from the time the young larva enters a boll until it reaches full

growth, when it may leave by a neatly cut circular or oval hole in the shell, there is no clearly visible external evidence to show that an unripe green boll is infested. Even with a good lens it is not always possible to say from an external examination only whether a boll has been attacked by this pest.

The nature and extent of the injury inflicted on the boll varies both according to its size when invaded and to the time of the year this takes place, and also according to the number of larvæ which may attack it. In the case of small bolls about the size of a large pea to a large hazel nut, growth is arrested and one of three things appears to follow :— the young boll may dry up, becoming quite hard and of a dark brown colour; or it may split, disclosing one or more tiny locks of poorly developed matted fibre (Plate VIII, Fig. 8), such bolls may and often do remain on the plant, or again they fall naturally or are perhaps knocked off by wind action on to the ground.

The pink bollworm is able to attain full growth even in a small boll — say the size of a Barcelona nut.

In the case of the unripe bolls of the first picking, the more advanced they are at the time of attack as regards the development of the fibre, the less will be the injury. Occasionally in spite of having been pierced all three locks of fibre in a boll may ripen in an apparently normal manner and injury will only be detected when the seeds are examined, and it will then be found that the contents of those in the attacked section or sections have been eaten. When the injury is so light as this, it indicates, generally speaking, that the boll was invaded by a single larva, but this is not invariably so, and two or even three bollworms may have matured in such a capsule. Under less favourable circumstances, one or more locks (Plate VIII, Figs. 2, 3, 5) will be injured to a greater or less extent, the fibre remaining in a hard lump (Plate VIII, Fig. 13) or partially fuzzing out, or again the boll may be so badly damaged as to produce no pickable fibre (Plate VIII, Figs. 6-7). A normal healthy ripe boll is shown on Plate VIII, Fig. 1 for comparison with the others. As to the extent which the larva severs the fibre in its passage to the seed we as yet lack information

of a precise nature, one would think it must be quite considerable and give rise to wastage in the spinning process. In some cases however, the larva may perhaps worm its way between the fibres and not sever them.

In the later pickings and likewise in a *late* first picking the proportion of badly injured and useless bolls is very much higher than in a normal first picking. In fact in a year like 1914, in many places it was the rule rather than the exception for a boll to give anything but badly damaged cotton in the second and third pickings. As will be described later this seems to be due partly to the greater average number of larvæ which attack each boll, and also to meteorological conditions — increased humidity causing rot and to more active proliferation. If an unripe boll that is badly attacked be cut in half, it may have the appearance shown at Fig. 3, Plate VI. The injury and its cause is obvious in such a case for it is probable that several pink bollworms will be found inside, and yet from the outside it may appear perfectly sound!! The seeds may be completely or partially hollowed out, or again perhaps only just touched; the septa dividing the loculi will have been pierced and there will be much pale or dark coloured frass and excrement in and amongst the seeds and fibre. A boll so injured will ripen and split open, but the fibre or what remains of it will be in hard locks and often some fibres on each side of the lock will adhere to the turned back shell of the boll as if at one stage the cotton had been somewhat glutinous and adhesive.

To take the opposite case, a boll may be cut in half and the only abnormal symptom which will be found is a small — sometimes so small as to be hardly distinguishable — yellowish or rust coloured stain between the shell and the fibre, suffusing a small area of the glistening and otherwise immaculate white surface of the latter (Plate VI, Fig. 2). This is generally, although not invariably, a sign that the boll has been successfully invaded by a pink bollworm and if careful search is made at this point a small glistening yellowish-white larva with dark polished head will be found amongst the fibres or between the lock of cotton and the shell of the boll; or again, the culprit may have already arrived at and entered a seed. In those cases where no bollworm can be found, the

yellowish stained fibre often indicates that a larva has attempted but failed to finally gain an entrance into the boll. When the larvæ are larger, say about 4 mm. to 6 mm. long, they are not difficult to find and their work is quite visible, their presence being revealed by pale granular and somewhat chalky looking frass and excrement (Plate VI, Fig. 1).

The young larva may occasionally tunnel in the shell before proceeding to the seeds and the larger larvæ may feed on this part also if there are a large number in the same boll.

NUMBER OF SEEDS INJURED BY THE LARVA.

The number of seeds injured by a larva is not as great as one would imagine. The following Table XXII shows that for 28 bolls the number of injured seeds per larva ranged from one to five, the average being 2.5 seeds. In this table an exit hole is calculated as being equivalent to one pink bollworm, but in one or two cases it is possible that an exit hole had been made by a larva, actually found in the boll, preparatory to making its escape. The extent to which the contents of the seeds is devoured varies considerably, if for example only one has been attacked it may be found to have been almost completely hollowed out. On the other hand, if two have been fed upon, the injury will be proportionally less to one or the other. If several seeds have been damaged, one or more may have had only a tiny cavity bored into the seed coat and perhaps the outer part of the kernel as well.

The area of the seed coat eaten varies also, a large piece may have been devoured or only sufficient to permit of the passage of the bollworm into the interior (Plate IV, Fig. 16). In addition to the seeds, the larvæ consume a certain quantity of the shell or carpel wall and perhaps of the unripe cotton fibre as well.

INJURY TO THE STEM OF THE COTTON PLANT.

It is only recently — July 1915 — that the pink bollworm has been observed to attack and injure the stem of cotton plants. This new work of the pest was brought to my notice by Sirri Effendi of this Society who

Table XXII.

Number of Seeds per Boll injured by a Pink Bollworm.

Number of Boll.	Number of Exit Holes in Boll.	Number of Full Grown Larvæ in Boll.	Number of $\frac{3}{4}$ Grown Larvæ in Boll.	Number of $\frac{1}{2}$ Grown Larvæ in Boll.	Total Number of Larvæ in Boll.	Total Number of Seeds in Boll.	Number of Sound Seeds.	Number of Attacked Seeds.	Per Cent of Attacked Seeds.	Number of Seeds Attacked per Larva.	Remarks.
1	"	2	1	"	3	19	10	9	47.3	3	
2	"	1	"	1	2	16	12	4	25	2	
3	2	"	1	"	3	17	11	6	35.3	2	
4	"	"	1	"	1	15	13	2	13.3	2	
5	1	"	"	"	1	16	13	3	18.7	3	
6	1	"	1	"	2	16	12	4	25	2	
7	"	1	"	"	1	16	12	4	25	4	1 seed touched only.
8	1	1	"	"	2	16	14	2	12.5	1	
9	"	"	1	"	1	17	15	2	11.7	2	ditto
10	"	1	"	1	2	8	5	3	37.5	1.5	
11	2	"	"	"	2	16	11	5	31.2	2.5	
12	"	"	1	"	1	6	3	2	33.3	2	
13	1	"	"	"	1	20	18	2	10	2	
14	1	"	"	"	1	15	10	5	33.3	5	3 seeds touched only.
15	1	"	"	"	1	19	17	2	10.5	2	
16	1	"	"	"	1	14	11	3	21.4	3	
17	1	"	"	"	1	14	12	2	14.2	2	
18	2	"	1	"	3	13	7	6	46.1	2	
19	1	"	"	"	1	14	12	2	14.2	2	
20	1	"	"	"	1	14	11	3	21.4	3	
21	1	"	"	"	1	14	12	2	14.2	2	
22	1	"	"	"	1	14	12	2	14.2	2	
23	"	1	"	"	1	20	18	2	10	2	
24	"	1	"	"	1	"	"	5	"	5	2 seeds hardly touched.
25	1	"	"	"	1	14	10	4	28.5	4	Seeds slightly injured.
26	1	"	"	"	1	14	12	2	14.2	2	
27	1	"	"	"	1	14	9	5	35.7	5	ditto
28	2	"	"	"	2	13	6	7	53.8	3.5	

Average Number of Seeds injured per Pink Bollworm = 2.5.

found several plants at the Bahtim Experimental Farm which had snapped off about six inches — in some cases more and in some less — above the ground. Examination showed that at the break the stem had been completely girdled and the culprit was found to be the pink bollworm. The young bollworm appears to enter the stem in the neighbourhood of a leaf axil and then works round under the bark or rhind and between the latter and the central woody part of the stem. The stem is of course much weakened and sooner or later is broken off by the action of the wind, or very frequently by the children when they take hold of the plant to look for the egg-masses of the cotton worm moth.

Fortunately this form of injury at present appears to be rare, only a plant here and there in a large field being so attacked. If the habit became at all general the damage would be serious as, practically speaking, the greater part of the boll bearing portion of the plant is destroyed at one blow and by a single pink bollworm.

MABROUM BOLLS.

« Mabroum » is a vernacular name given to those bolls which ripen or become dry and hard either without opening at all or else, in some other cases, the locks just split apart at the tips of the boll (Plate IV, Fig. 13, and Plate VIII, Figs. 9 and 10). The colour of these particular bolls is characteristic, varying from dark brown to a bright red-brown. The exact cause and manner in which bolls become mabroum is not known with certainty, but it is noteworthy that in a very large number, if not in all cases, they have been pierced by a pink bollworm or an *Earias* larva, and it may well be that this is the predisposing cause, the injury to the shell admitting certain fungi or bacteria that complete the process. If a mabrouma boll is opened, the locks of cotton will be found to be perfectly formed but hard and felted and the fibre very weak in texture — in fact practically rotten. In colour it is generally brownish or rusty coloured or again sometimes reddish-pink. The seeds may also be this colour and are sometimes full of a soot-like powder, the spores of a fungus. Mabroum

bolls may be quite common, but they cannot be compared in number with the ordinary bollworm-damaged bolls.

PROLIFERATION CAUSED BY THE PINK BOLLWORM AND ITS EFFECTS ON THE ATTACKED BOLL.

Although proliferation is not noticeably in evidence in the early stages of the attack — that is to say, in July and August — in the latter half of September and in October and November, when several larvæ may occur in one boll and the weather is hot and damp, this process in attacked bolls is quite common. Proliferation may be described as being :—

« The development of numerous elementary cells from parts of the bud or boll which are themselves normally the ultimate product of combinations of much more highly specialized cells, which are placed so loosely together that the resulting formation is of a soft texture and has a granular appearance which may be plainly seen with the unaided eye * »

Green unripe bolls which have split longitudinally along a locular suture (Plate V, Fig. 3), or even in some cases transversely, may be found frequently at this time. The split discloses the undeveloped white lock of fibre and sometimes the seeds. These parts generally become brown owing to exposure to the air. The premature splitting is due to the pressure of the proliferating parts inside, consequent on the irritation set up by the pink bollworm working in the interior. If a green boll is cut in half with a sharp knife it may be found to have the following appearance :— the contents will be more or less translucent and gelatinous looking, or perhaps greyish and corneous or horn-like (Plate VII, Fig. 1). Instead of the fibre having developed a mass of rather loose cellular tissue has taken its place. The seeds, which appear to proliferate very readily and perhaps set up or stimulate the process in other parts of the boll, may be much enlarged and malformed also and the interior

* Bulletin N° 54, Bureau of Entomology, U.S.A. : Proliferation, by W. E. Hinds, Ph. D., page 8.

will be full of loose or rather dense proliferous tissue instead of the developed cotyledenous leaves of the embryo that one finds in the seeds of a healthy boll, or even in an attacked one in which proliferation has not occurred (Plate VI, Fig. 2). Proliferated seeds frequently bear a resemblance to a canine-like tooth.

On stripping the shell from an attacked boll translucent green swellings or opaque white pustular and sometimes mushroom-shaped swellings may be found on the inside of the shell, apparently arising from the carpel lining. They often leave a corresponding depression on the lock of unripe fibre which may be stained yellowish brown at this point. The swellings are due to proliferation and are believed to be either due to failed attempts on the part of a young pink bollworm to bore through the shell or perhaps also to the piercing of the latter by the cotton seed bug (*Oxycarenus hyalinipennis*).

No instance has been observed in which a pink bollworm has been killed by proliferation as is by no means infrequent in the case of the Mexican cotton boll-weevil (*Anthonomus grandis*, Boh.) in the United States. The eggs or pupæ of this pest become enclosed and crushed to death by the rapid production of proliferous cellular tissue in the infested bolls.

In Egypt this process set up by the agency of the pink bollworm is undoubtedly important since it seems to accentuate the damage of the larvæ, transforming what should be fibre into an abnormal and useless cell formation. A boll may be attacked by a larva or larvæ in one lock only and yet one or both of the other sections may be affected by proliferation and much injured.

It may be found that some of our varieties of cotton here proliferate much more readily than others. Whether or not the weather influences the process in Egypt might also be worked out as a matter of interest. In America it seems that meteorological conditions do not influence it.

Table XXIII.

The Number of Teel Seeds per Seed-Capsule Injured by a Pink Bollworm.

Number of Capsule.	Total Number of Seeds in Capsule.	Unattacked Seeds.	Per Cent of Total.	Attacked Seeds.	Per Cent of Total.	Number of Pink Bollworms in Capsule.	Number or Average Number of Damaged Seeds per Larva.
1	21	19	90.5	2	9.5	1	2*
2	15	6	40	9	60	2	4.5
3	22	10	45.4	12	54.6	2	6**
4	24	19	79.2	5	20.8	1	5
5	20	10	50	10	50	2	5
6	24	18	75	6	25	1	6
7	27	7	26	20	74	4	5
8	20	16	80	4	20	1	4
9	21	11	52.3	10	47.7	2	5
10	20	17	85	3	15	1	3
11	14	9	64.3	5	35.7	1	5
12	17	12	70.5	5	29.5	1	5
13	22	18	81.8	4	18.2	1	4
14	15	11	73.3	4	26.7	1	4
15	17	1	5.8	16	94.2	4	4
16	18	13	72.2	5	27.8	1	5
17	20	11	55	9	45	2	4.5
18	24	20	83.3	4	16.7	1	4
19	22	4	18.2	18	81.8	4	4.5
20	17	13	76.5	4	23.5	1	4
21	25	19	76	6	24	1	6
22	22	13	59	9	41	2	4.5
23	24	19	79.2	5	20.8	1	5
24	17	7	41.2	10	58.8	2	5
25	20	13	65	7	35	2	3.5
26	21	15	71.4	6	28.6	2	3
27	24	12	50	12	50	3	4
28	14	6	42.8	8	57.2	2	4
29	23	17	73.9	6	26.1	1	6
30	14	11	78.5	3	21.5	1	3
31	21	17	80.9	4	19.1	1	4
32	14	4	28.5	10	71.5	2	5
33	13	1	7.7	12	92.3	4	3
34	26	20	77	6	23	1	6
35	20	8	40	12	60	3	4
36	18	13	72.2	5	27.8	1	5
37	22	9	40.9	13	59.1	3	4.3
38	21	15	71.4	6	28.6	1	6
39	19	15	78.9	4	21.1	2	2***
40	23	4	17.4	19	82.6	4	4.75
41	23	14	60.8	9	39.2	2	4.5
42	22	19	86.3	3	13.7	1	3
43	14	10	71.5	4	28.5	1	4
44	24	16	66.6	8	33.4	2	4
45	29	0	00.0	29	100	8	3.6

46	21	16	76.2	5	23.8	1	5
47	21	16	76.2	5	23.8	1	5
48	18	14	77.7	4	22.3	1	4
49	17	11	64.7	6	35.3	2	3
50	23	10	43.5	13	56.5	3	4.3
51	19	13	68.4	6	31.6	1	6
52	21	2	9.5	19	90.5	4	4.75
53	16	7	43.7	9	56.3	2	4.5
54	21	13	62	8	38	2	4
55	16	0	00.0	16	100	3	5.3
56	23	18	78.2	5	21.8	1	5
57	16	12	75	4	25	1	4
58	20	16	80	4	20	1	4
59	28	18	64.3	10	35.7	3	3.3
60	14	12	85.7	2	14.3	1	2
61	18	9	50	9	50	2	4.5
62	17	14	82.3	3	17.7	1	3
63	15	10	66.6	5	33.4	1	5
64	16	11	68.7	5	31.3	1	5
65	23	17	73.9	6	26.1	1	6
66	34	16	47	18	53	4	4.5
67	20	15	75	5	25	1	5
68	19	15	78.9	4	21.1	1	4
69	16	11	68.7	5	31.3	1	5
70	20	15	75	5	25	1	5
71	20	7	35	13	65	3	4.3
72	22	19	86.3	3	13.7	1	3
73	22	16	72.7	6	27.3	2	3
74	28	19	67.8	9	32.2	2	4.5
75	16	8	50	8	50	2	4
76	14	9	64.3	5	35.7	1	5
77	13	6	46.1	7	53.9	1	7
78	17	12	70.6	5	29.4	1	5
79	16	11	68.7	5	31.3	1	5
80	26	14	53.8	12	46.2	3	4
81	13	10	77	3	23	1	3
82	24	16	66.6	8	33.4	2	4
83	18	8	44.4	10	55.6	2	5
84	14	9	64.3	5	35.7	1	5
85	30	26	86.6	4	13.4	1	4
86	17	1	6	16	94	3	5.3
87	22	17	77.2	5	22.8	1	5
88	19	16	84.2	3	15.8	1	3
89	22	12	54.5	10	45.5	2	5
90	17	11	64.7	6	35.3	2	3
90	1,795	1,100	61.3	695	38.7	161	394.90
Average.....	19.94	12.22	61.3	7.72	38.7	1.79	4.38

* A small undersized larva. — ** Several seeds only just touched. — *** 1 Larva quite small in a single seed.

THE ATTACK OF THE PINK BOLLWORM ON TEEL OR HEMP AND BAMIA OR OKRA.

Teel or Hemp. — The attack of the pink bollworm on teel or hemp (*Hibiscus cannabinus*) calls for no special remark, the attacked capsule exhibiting no interesting external characteristics other than exit holes, which sometimes become sealed over by exudation (? proliferation).

Table XXIV.

Weight of Sound Teel Seeds.

NUMBER OF SEED.	WEIGHT OF SEED.	NUMBER OF SEED.	WEIGHT OF SEED.
	Grams.		Grams.
1	0.038	*Carried forward.*	0.487
2	0.035	15	0.029
3	0.036	16	0.035
4	0.037	17	0.038
5	0.034	18	0.037
6	0.033	19	0.034
7	0.036	20	0.030
8	0.035	21	0.032
9	0.034	22	0.034
10	0.033	23	0.027
11	0.033	24	0.032
12	0.034	25	0.037
13	0.037		
14	0.032	25	0.852
Brought forward.	0.487	*Average*	0.034

The larvæ feed on the seeds, a variable number of which are eaten by each bollworm during its life. Table XXIII shows the number of attacked seeds and the number of full-grown pink bollworms (resting larvæ) in each of 90 attacked teel seed-capsules. The average number of seeds (4.47) the contents of which are eaten or partially eaten is higher than the number of seeds injured in a cotton boll; this, however, is only to be expected when the difference in the size of the seeds is

taken into account. The weight of seed contents (0.06 grammes) eaten by a single pink bollworm, calculated on the ripe seed weights, is much about the same both in the case of teel and cotton (see Tables XXIV and XXV also XII and XIII).

A single fruit of teel contains sufficient seeds to feed eight pink bollworms to full growth, but to find this number of larvæ in one capsule is very exceptional, from one to three being the more usual number.

When full grown the larva spins a cocoon amongst the seeds on which it has been feeding, generally from four to five seeds in one loculus area attached together forming a small cone-like mass (Plate IV, Figs. 17-18). In some cases resting larvæ have been found spun up in a *single* teel seed : these larvæ have always been very small and undersized and could at the best only give rise to very small moths of low reproductive powers. Such larvæ may have been unable to complete their normal growth owing to the seeds becoming ripe and too hard for them to feed upon.

Teel, judging by the number of sound capsules it is possible to find right at the end of the season, would seem not to be such a favourite food plant of the pink bollworm as cotton.

Table XXVI shows the number of sound and attacked capsules on several samples of teel received in February 1915.

Bamia or Okra. — In the case of bamia (*Hibiscus esculentus*) a vegetable, the pink bollworms feed chiefly on the seeds working from seed to seed in one loculus or compartment of the fruit, or they may pierce the septum or dividing wall and attack the seeds in a second loculus. It has been observed that the young larvæ frequently commence their attack on a bamia fruit at the tip under the shelter of the dead flower, in such cases as it has remained attached to this part. They may feed on the exterior wall at this point for some little time before boring into the interior of the fruit to complete their growth on the seeds.

When full-fed the larvæ may spin their pupal or resting stage cocoons inside the fruit between two or more seeds (Plate IV, Fig. 14) or quite

Table XXV.

Loss in Weight of Teel Seeds (*H. cannabinus*)

Injured by the Pink Bollworm.

Each capsule had been attacked by one larva only.

1 NUMBER OF CAPSULE.	2 WEIGHT OF PINK BOLLWORM.	3 TOTAL WEIGHT OF THE ATTACKED SEEDS.	4 NUMBER OF ATTACKED SEEDS.	5 WEIGHT IF ALL ATTACKED SEEDS HAD BEEN SOUND AND IF THEY HAD BEEN OF AVERAGE WEIGHT OF 0.034 GRAMS.	6 DIFFERENCE BETWEEN (3) and (5) = LOSS IN WEIGHT OF ATTACKED SEEDS.	7 PER CENT LOSS IN WEIGHT ON TOTAL ATTACKED SEEDS.
	Grams.	Grams.		Grams.	Grams.	
1	0.027	0.096	4	0.136	0.040	29.3
2	0.028	0.081	4	0.136	0.055	40.4
3	0.031	0.080	5	0.170	0.090	53
4	0.030	0.114	5	0.170	0.056	33
5	0.026	0.105	5	0.170	0.065	38.2
6	0.025	0.142	5	0.170	0.028	16.4
7	0.021	0.101	4	0.136	0.035	25.7
8	0.021	0.103	5	0.170	0.067	39.4
9	0.024	0.086	4	0.136	0.050	36.7
10	0.031	0.042	5	0.170	0.128	75.3
11	0.024	0.088	4	0.136	0.048	35.2
12	0.026	0.063	4	0.136	0.073	53.6
13	0.022	0.145	5	0.170	0.025	14.7
14	0.026	0.081	4	0.136	0.055	40.4
15	0.036	0.103	5	0.170	0.067	39.4
16	0.026	0.117	5	0.170	0.053	31
17	0.020	0.092	4	0.136	0.044	32.3
18	0.024	0.081	5	0.170	0.089	52.3
19	0.017	0.074	4	0.136	0.062	45.5
20	0.035	0.067	4	0.136	0.069	50.7
21	0.023	0.063	4	0.136	0.073	53.6
Totals..	0.543	1.924	94	3.196	1.272	»
Average.	0.0258	0.0916	4.47	0.152	0.060	39.5 %

free of the seeds between two of the septa which divide up the fruit into a number of compartments or loculi.

Table XXVI.

The Number of Resting Pink Bollworms Found in Seed Capsules of Teel (*H. cannabinus*).

DATE RECEIVED.	LOCALITY FROM WHICH SAMPLE WAS RECEIVED.	NUMBER OF CAPSULES EXAMINED.	NUMBER OF CAPSULES ATTACKED BY PINK BOLLWORM.	PER CENT OF TOTAL.	NUMBER OF CAPSULES INFESTED WITH LIVE PINK BOLLWORMS.	PER CENT OF TOTAL.	TOTAL NUMBER OF LIVE PINK BOLLWORMS FOUND.
15. I. 15	Bahtim near Cairo.....	513	377	**73.4**	312	**60.8**	554
17. II. 15	Teh-el-Baroud	100	26	**26**	17	**17**	21
22. II. 15	Tanta.....	100	34	**34**	18	**18**	21
20. II. 15	Mit Ghamr.....	70	54	**77**	26	**37**	33
20. II. 15	Aga.....	78	35	**44.8**	17	**21.7**	21
20. II. 15	Simbellawain.....	100	73	**73**	41	**41**	51
12. II. 15	Zagazig.....	100	40	**40**	21	**21**	26
12. II. 15	Bordein.....	100	21	**21**	8	**8**	8
12. II. 15	Shibin-el-Kom.....	100	80	**80**	53	**53**	75

Bamia fruits, when attacked by the newly hatched larvæ of *Earias insulana* may exude a mucilaginous liquid at the point of the attack. In some cases this appears to cause considerable hinderence to the entry of the young bollworm which may be drowned or become so «gummed up» or sticky that it perishes. Whether this also occurs in the case of the pink bollworm is not known, but it is probable that it does so.

Like teel, bamia also seems a less favoured food plant than cotton.

THE DIFFERENCE BETWEEN THE WORK OF THE ORDINARY BOLLWORM AND THE PINK BOLLWORM.

No doubt it will have been remarked by many that the injury caused to a boll by an individual pink bollworm is, generally speaking, much less than that caused by a larva of *Earias insulana* — the ordinary cotton

bollworm. It is not due simply to a matter of size or to the latter species eating more, but it seems to result more particularly from the fact that the *Gelechia* larva keeps no open or free passage to the exterior during its life in the boll; whereas generally speaking, the *Earias* larva does so, enlarging, as becomes necessary, the original entrance hole. This open wound as it were, allows the interior of the boll to be readily invaded by bacteria which set up fermentation, and thus the mere mechanical injury caused by the destruction of the tissues by the jaws of the larva is still further accentuated. Furthermore, the spores of a sooty-mould fungus may at times gain entry and fill the damaged seeds, and perhaps other parts as well, with a black soot-like powder composed of countless numbers of its spores. On the other hand, during the three weeks of its life the pink bollworm remains entirely sealed up in the boll, only leaving a small circular or oval hole when it reaches, or shortly before it reaches, full growth and vacates the boll in order to pupate. By this time the boll or that part of it which has escaped injury will frequently be well advanced towards ripeness and thus the danger of infection through the exit hole and subsequent fermentation and decay will be much lessened. However, in the latter part of September and in October and November the injury is proportionally greater and more like that which the *Earias insulana* larvæ give rise to. The reason for this is that there may be several pink bollworms of different ages in the same boll and one or more of them may leave a long time before the others. Bacteria and fungi thus have the entry *via* an exit hole whilst the boll is still very green and moist inside and will find suitable ground for increase in the damaged interior, and on the excrement of the remaining larvæ. Thus at this time it is by no means uncommon to find bolls which are quite dark and more or less rotten inside consequently the proportion dirty cotton and cotton stained to a yellowish or brown colour that remains in hard felted locks is very high indeed in the late pickings.

HABITS OF THE FULL-GROWN PINK BOLLWORM.

PREPARATION FOR PUPATION.—When full-grown, the pink bollworm may do one of three things:

1. It may leave the green boll and form a cocoon in which to pupate in or under some convenient shelter on the ground.

2. It may remain and pupate in the green boll, or in the ripe boll, according to whether or not it reaches maturity before the boll.

3. It may remain as a larva in a seed or seeds of a green boll (which will in most cases finally ripen and split open) resting in this stage for a period of six months or perhaps less, up to more than one year before it finally turns to the pupa or chrysalis stage and subsequently gives rise to the adult insect or moth.

In July, August and early September the majority of the mature pink bollworms appear to leave the unripe green bolls by a more or less circular exit hole. This is clean cut and rather characteristic, being different, speaking in a general way, from the holes made by *Earias* larvæ which are more irregular or oval in shape and frequently much larger than is necessary for the passage of the larva. At this period a small circular or oval hole in the shell that has been obviously cut from the inside generally denotes that the boll has harboured a pink bollworm which, however, has now left. It does not, as is sometimes thought to be the case, definitely indicate the presence of a pink bollworm inside — the exit hole being mistaken for the entrance hole of the larvæ assumed to be in the interior. So far I have never found a *Gelechia* larva which has left one boll and commenced to bore into another from the outside. I would not say that this never occurs, as once or twice certain indications have led me to think this may sometimes happen, but at the most very rarely under natural conditions.

Table XXVII shows the number of the attacked bolls with exit holes which contained no pink bollworms or else pink bollworms of different

Table XXVII.

Number of Green Bolls

with Exit Holes in Shell which Contain or do not Contain Pink Bollworms.

DATE.	1 TOTAL NUMBER OF ATTACKED BOLLS EXAMINED.	2 NUMBER OF ATTACKED BOLLS SHOWING NO EXTERNAL SIGNS OF ATTACK.	PER CENT OF TOTAL (1).	3 NUMBER OF ATTACKED BOLLS WITH EXIT HOLES IN SHELL.	PER CENT OF TOTAL (1).	NUMBER OF ATTACKED BOLLS WITH EXIT HOLE IN SHELL AND NO PINK BOLLWORM INSIDE.	PER CENT OF TOTAL (3).	NUMBER OF ATTACKED BOLLS WITH EXIT HOLE AND FULL GROWN PINK BOLLWORMS INSIDE.	PER CENT OF TOTAL (3).	NUMBER OF ATTACKED BOLLS WITH EXIT HOLE AND $\frac{3}{4}$ GROWN PINK BOLLWORMS INSIDE.	PER CENT OF TOTAL (3).	NUMBER OF ATTACKED BOLLS WITH EXIT HOLE AND $\frac{1}{2}$ GROWN TO SMALL OR VERY SMALL PINK BOLLWORMS INSIDE	PER CENT OF TOTAL (3).
1914.													
July.....	30	16	53	14	47	14	100	"	"	"	"	"	"
August	54	21	39	33	61	31	94	2	6	"	"	"	"
September..	2,525	1,172	46	1,357	54	711	52	411	30	131	9.6	176	13
October....	289	162	56	127	43.6	47	37	47	37	19	15	35	27.5

ages. It will be seen that the proportion varies according to the time of the year. These figures will be referred to again when we consider the utility of removing the infested bolls early in the season as a control measure.

During the latter part of the season it is of course obvious that one is likely to find exit holes in the shell of a boll and at the same time large pink bollworms in the interior. This is due to difference in age, some larvæ reaching full-growth and cutting their way out before the others. At any stage of the attack a bollworm nearing full-growth may cut a hole in the boll shell to the outside, and through which « frass » is sometimes thrown out, some little time before it actually leaves the boll to pupate. Further information is required on this habit.

Whether when a larva leaves the boll it simply tumbles to the earth, crawls down the branches and stem or lowers itself by a thread of silk, I do not know, not having been lucky enough to observe this act. The full-grown larva has very poor clinging powers in its prolegs and is the poorest of climbers. If it has to ascend a smooth and upright surface the larva relies on spinning a foothold of silk to accomplish this task. A pink bollworm can lower or drop itself at the end of a silken thread, but the latter frequently breaks before the ground is reached; it can also with great difficulty wind itself again by this means if necessary.

The time of day at which the larva generally leaves the boll — whether during the night or the day-time — is also both of interest and importance from the point of view of the natural mortality which may occur at this period of its life, since it would tell us to some extent the particular set of natural enemies by which it might be attacked and destroyed.

When the pink bollworm remains in the boll to pupate without undergoing any resting stage, its preparations for this important event appear to vary according to circumstances. It may happen that the boll becomes ripe and splits before the larva is full-grown and whilst it is still feeding in the interior of a seed. In this case it may finally pupate in the seed in which it has been feeding or construct a cocoon amongst the fibre without having to make any very special provision for its escape when it

becomes a moth. If, however, the boll is nearly ripe but still green and unsplit the larva may spin a cocoon in one of the eaten out seeds after preparing a way of escape for the moth by cutting a circular hole through the shell to the outside. This hole is kept closed by retaining in position the cut out circular piece of shell by strands of silk. This exit is connected up to the seed in which the larva pupates in a silken cocoon by an extension of the latter, thus forming a silken tube or tunnel. Pupation in the green bolls in this way is believed to be rare. The number of larvæ that pupate in any manner actually in the bolls during the summer months appears to be very small.

In 1913, during an examination of 6,575 infested green bolls only three pupæ were found; and in 1,761 ripe bolls 23 pupæ were observed either in a seed or amongst the fibre. In 1914, an examination of 1,427 unripe bolls gave negative results as regards pupation and in 3,060 ripe bolls 175 pupæ were found. In this case it is probable that a number of larvæ had been, owing to conditions, forced to pupate in the fibre of the ripe bolls; the latter were in bags together with a certain number of partially ripe bolls in which no doubt larvæ were still feeding at the time of picking. The great majority of larvæ seem to seek other situations in which to pupate during the active period.

Situations in which the pupa is found. — Before recording local observations it is of interest to examine what other writers have to say on this subject.

Maxwell-Lefroy says in « Indian Insect Pests »[22], page 93 :—

« The full-grown larva forms a slight cocoon of silk, in the boll or on the bracts or leaves of the cotton. In unirrigated black cotton soil this may be found in a crack of the dry soil. »

The Deputy Director of the Cawnpore Farm and other Experiment Stations[23] observes, page 17 :—

« The larvæ generally pupate inside the bolls; less frequently they come out and pupate between the bolls and the bracts, when they form a slight transparent cocoon. They

may also be found amongst the picked unginned cotton as larvæ, or having pupated either in the hollowed out seed or amongst the fibre. They will also go into the earth and pupate, but it is not their general custom.»

Fullaway [24] says :—

«The larva usually pupates within the boll, forming a slight cocoon in the cotton square.»

Our experience here in Egypt differs slightly from the above observations, but more in degree than in kind. For example, we look upon pupation in the boll during the summer months as being more in the nature of an exception rather than the rule. With regard to the pink bollworm pupating between the boll wall and the involucre — this has been observed in two cases only during the past three years. This method of pupation was very characteristic. A shallow oval cavity had been excavated in the shell of the boll and part of the involucre had been utilized to form the roof of the pupal chamber, the remaining spaces being filled in with silk and small pieces of the boll which had been bitten out during the formation of the cavity. It is of importance to note that in both cases this form of cocoon was found in a parcel of green bolls sent to the laboratory from the provinces, so it is quite probable that they were formed in transit and were thus largely due to abnormal or novel surroundings.

Pupation seems most often to take place on the ground under the fallen leaves, or in the fold of a dead leaf or again between two dead leaves, also in old bolls which have dropped or been broken off, and under or attached to small lumps of earth. In fact they may be looked for amongst any shelter of this kind. One situation was noted that seems to be especially favoured by the larvæ as a haven to pass the pupal stage, this was furnished by the dead flowers which are of course very numerous below the plants.

In captivity, the larvæ freely form their cocoons on the surface of the soil employing fine particles of the latter to mix with the silk, the result being quite criptic. They do this even when other suitable shelter is available.

Probably the larvæ rarely if ever actually enter compact soil to pupate,

although they might well and as a matter of fact do choose a crack in the soil, as we know from other observers, to pass the chrysalis stage. Caterpillars which normally spin slight silken cocoons do not as a rule pupate under ground.

OTHER SITUATIONS IN WHICH THE PUPA MAY BE FOUND.

It happens in practice that large numbers of pink bollworms are picked with the ripe cotton before they have reached full growth and are transported to the store or the ginning factory. Here they may issue from the seeds and the majority will (if they have time) pupate amongst the fibre if the cotton has not been ginned, or they may be looked for in a crack in the wall or floor and similar places. Many also pass through the gins inside the seeds and are bagged up with the latter. When they finally reach full growth they force or bite their way through to the outside of the sacks, spin a cocoon and pupate. The following letter received from Osman Effendi Abaza, State Domains, Sakha, is of great interest as regards this question. He says :—

"In the cotton seed store, where our seed of the 1914 crop is kept, it was noticed that a great number of the larvæ of the Pink Bollworm came out and pupated in the outside portion of the sacks on the lines of separation made by one sack lying on the top of the other, thus making a chain of pupæ in their cocoons. This movement continued up to October 15th, but after this date the emergence of larvæ from the seed ceased."

One would expect to find numbers of resting pink bollworms in cotton stores, cotton seed stores and ginning factories, in cracks and crevices of the walls or floor, under sacks etc., but so far this has not been our experience, but possibly we have either overlooked the pests or else have not examined sufficient of these places to form a just conclusion on the question.

VARIATION IN THE FORM OF THE COCOON.

The cocoon in which a larva pupates is different in form and size to that in which it passes the resting stage. In the former case it is elongate and oval (Plate IV, Fig. 10) and of a rather lighter and more

loosely woven texture than the cocoon of a resting larva. The latter is very closely woven — so much so that it is water tight, at all events for short period — and is small and round in form, the larva being tightly curled up in it in a head to tail position (Plate IV, Fig. 9). If the larvæ happen to make their resting cocoons in cotton fibre, the latter seem to be especially liable to be spherical in form, more so perhaps than when they are spun in a cavity in a cotton seed or between two seeds. When the pink bollworm is ready to pupate it needs more room in order that it may lie stretched out, and so perforce it has to construct a cocoon on different lines.

THE PUPA STAGE.

Description of the pupa. — The pupa (Plate IV, Fig. 8) varies from 5.75 mm. to about 8 mm. in length by 2.5 or slightly less to 2.75 mm. in width. The average-sized pupa ranges from 6 to 7 mm. in length. The colour is shiny yellowish brown. The cremaster consists of a short stiff spine and a number of small hooklets. The skin is hairy, the hairs being short and tawny in colour.

Duration of the pupal stage. — The duration of the pupal stage varies according to season — cold retarding it, but there also seems to be a certain amount of individual variation which at times is perhaps abnormal. Reference to Table XXVIII shows that for the summer months the time actually passed in the pupal stage varies from seven to twelve days, the average being about ten. The pre-pupal stage (that is the time during which the pupating larva rests in its cocoon before throwing off its last larval skin thus disclosing the pupa or chrysalis) at this season would appear to vary from two to seven days, but the average is about four, or three to four. There seems little doubt that as regards the observations in Table XXVIII the pre-pupal stage depends to a great extent on whether or not the larva was fully fed when removed from food; and again, whether after a long resting period it was really ready to pupate or was forced to leave this state prematurely by abnormal circumstances.

Table XXVIII.

Duration of the Pupa Stage.

NUMBER OF INDIVIDUAL.	LARVA SPUN COCOON.	LARVA HAD CHANGED TO PUPA STAGE.	A. DURATION OF PRE-PUPAL QUIESCENT PERIOD.	MOTH EMERGED NIGHT OF	B. DURATION OF ACTUAL PUPAL STAGE.	TOTAL DURATION OF PUPAL PERIOD = A + B.	SITUATION WHERE KEPT.
1	November 26.	December 3..	7 days.	January 13...	42 days.	49 days.	In Lab^{ry}.
2	— 26.	— 3..	7 —	— 13...	42 —	49 —	—
3	— 26.	— 3..	7 —	— 20...	49 —	56 —	—
4	— 26.	— 3..	7 —	— 20...	49 —	56 —	—
5	— 26.	— 3..	7 —	— 20...	49 —	56 —	—
6	December 7..	— 12..	5 —	— 27...	20 —	39 —	—
7	— 7..	— 22..	15 —	March 24....	93 —	108 —	—
9	— 9..	— 26..	17 —	April 14.....	110 —	127 —	—
10	March 30....	?	?	— 10.....	10 —	10 + ?	—
11	May 5.....	"	"	May 23.....	"	19 days.	—
12	— 5.....	"	"	— 27.....	"	23 —	—
13	— 5.....	"	"	— 29.....	"	25 —	—
14	— 11.....	"	"	— 23.....	"	13 —	—
15	— 11.....	"	"	— 26.....	"	16 —	—
16	— 11.....	"	"	— 28.....	"	18 —	—
17	June 7.....	June 11.....	4 days.	June 20.....	10 days.	14 —	—
18	— 5.....	— 8.....	3 —	— 17.....	10 —	13 —	—
19	— 7.....	— 9.....	2 —	— 18.....	10 —	12 —	—
20	— 7.....	— 11.....	4 —	— 20.....	10 —	14 —	—
21	— 7.....	— 11.....	4 —	— 20.....	10 —	14 —	—
22	— 7.....	— 10.....	3 —	— 17.....	8 —	11 —	—
23	— 7.....	— 10.....	3 —	— 20.....	11 —	14 —	—
24	— 7.....	— 10.....	3 —	— 20.....	11 —	14 —	—
25	July 23.....	"	"	July 31.....	"	9 —	—
26	— 23.....	"	"	August 1.....	"	10 —	—
27	— 24.....	"	"	— 2 a.m.	"	10 —	—
28	— 29.....	August 1.....	3 days.	— 8.....	8 days.	11 —	Insectary.
31	September 20.	September 23.	3 —	September 30.	8 —	11 —	In Lab^{ry}.
32	— —	— 23.	3 —	— 30.	8 —	11 —	—
33	— —	— 23.	3 —	October 2....	10 —	13 —	—
34	— —	— 24.	4 —	— 1....	8 —	12 —	—
35	— —	— 24.	4 —	— 2....	9 —	13 —	—
36	— —	— 25.	5 —	— 3....	9 —	14 —	—
37	— —	— 25.	5 —	— 4....	10 —	15 —	—
38	— —	— 25.	5 —	— 4....	10 —	15 —	—
39	— —	— 27.	7 —	— 6....	10 —	17 —	Insectary.
40	— —	— 24.	4 —	— 4....	11 —	15 —	—
41	— —	— 24.	4 —	— 4....	11 —	15 —	—
42	— —	— 25.	5 —	— 4....	10 —	15 —	—
43	— —	— 25.	5 —	— 6....	12 —	17 —	—
44	— —	— 26.	6 —	— 6....	11 —	17 —	—
45	— —	— 26.	6 —	— 6....	11 —	17 —	—
46	— —	— 26.	6 —	— 7....	12 —	18 —	—
47	— —	— 27.	7 —	— 7....	11 —	18 —	—
48	— —	— 28.	8 —	— 10....	13 —	21 —	—
49	— —	— 28.	8 —	— 10....	13 —	21 —	—

The total duration of the pupal stage from the time the larva spins its cocoon until the moth emerges varies during May and June from eleven days to just over three weeks, the average being about 14½ days. In July and August — the Egyptian mid-summer — the range is from eleven to thirteen days, the average being eleven days and perhaps even this is a little high. In September the pupal stage is still short, observations made on a series of twenty-two larvæ at this period showed the pre-pupal stage to range from three to eight days, average about five; the actual pupal stage was from eight to thirteen days, the average being about ten and the total duration from eleven to twenty-one days, average 15.7. The pre-pupal stage varied considerably, probably because the larvæ were removed from the green bolls and thus some may not have been really full-grown at the time they were judged to be so.

During the winter those larvæ which do pupate may pass seven to eight weeks in this stage or again they may remain as long as four months before the pupa gives rise to the moth. We expect to find that such long pupal stages as the latter are the exception rather than the rule, for all our observations tend to show that very few larvæ pupate during the winter months unless they have been subjected to abnormal conditions or disturbance in some form or another. As regards the change of the resting larvæ to the pupal stage, it has been noted so far, that in the vast majority of cases the moth seems to emerge after a normal interval.

THE MOTH STAGE.

Description of the moth. — The moth (Plate IV, Fig. 1) of the pink bollworm measures about 16 mm., in wing expanse, but some specimens are very much smaller, being little more than half the size. It is a somewhat drab and inconspicuous insect, the general colouring of the wings being brown — a rather metallic or coppery brown when the moth is alive and freshly emerged. There are several areas of dusky or blackish scales on the median area and towards the apex of the fore-wings, which is blackish; the hind wings are greyish with a silvery sheen.

They are provided with a long fringe of grey hair-like scales. The legs are dark brown, almost black, with pale joints. The head and thorax are the same colour as the wings, although in some the head tends to be a little lighter. The abdomen is paler and ends in a tuft of somewhat ocherous scales.

The following is the technical description of the moth.[25]

« Dark fuscous brown, the head and thorax somewhat lighter in colour. Anterior wings with an undefined round blackish spot on the disk a little above the centre, and a fascia of the same colour crossing the wings a little above the apex, which itself is black. Underwings of a silvery grey, darker towards the hinder margin. Legs and tarsi black-brown, with the joints light. Length 4-10ths inch. »

When at rest the wings are closed one over the other like scissor blades *flat* on the back. This position of the wings enables the moth to be easily distinguished from most of the other small dark coloured moths which might be mistaken for it.

Habits of the moth. — The pink bollworm moth is nocturnal in its habits, and during the day it lies very closely hidden. One may walk through a field of cotton teeming with pink bollworms and yet not disturb a single moth into flight. At dusk they emerge to lay their eggs and to feed. The moths are not, although their flight is slow, easy to see at night owing to their dark colouring. One rather noticeable characteristic of the species is its very quick and rather jumpy walk or one might say run.

Time of emergence of the moth from the pupa. — When this takes place in the majority of cases we do not know, but probably towards evening; it is however by no means uncommon for the moths to leave the pupa during the morning.

Attraction to light. — Both sexes come readily to lamps at night. This question is more fully dealt with under « Methods of Control ».

Attraction to sweet substances. — Few experiments have been made in this direction so far, but I have found that the moths of *G. gossypiella* may be attracted to sweet fermented substances such as a mixture of beer and mollases.

Interval elapsing between the emergence of the female moth and oviposition. — Generally speaking, the female moth is ready to lay eggs on about the third or fourth night after she has left the pupa. The length of this interval is most probably influenced by temperature and perhaps by other factors also.

Difference between the sexes. — There seems to be no conspicuous character by which the sexes may be distinguished readily and with certainty during life. The abdomen of the male is, as a rule, narrower and more gradually tapering than that of the female but if this character is solely relied on one is apt to make mistakes. After the moth is dead its sex can of course be readily ascertained by dissection or by laying it on its back and gently pressing with a slight forward movement on and towards the tip of the abdomen with the first finger or a blunt pointed instrument. By this means a pale tube will be pressed out — the ovipositor if a female : or if it is a male, two small fan shaped tufts of hair-like scales, parts of the genitalia, will be exposed.

Proportion of the sexes. — Of the 9,194 moths bred in the laboratory, 4,868 or 52.9 per cent were males and 4,301 or 46.7 per cent were females. Thus the sexes seem to be produced in, roughly speaking, equal numbers. These moths were bred out over a period of more than one year and the bulk of them were from resting larvæ. Tables XXIX and XXX show respectively the varying weekly and monthly proportion between the two sexes. It will be seen from these that in the autumn months the females appear to predominate very slightly, and in the early summer the sexes are equal, and in the later summer — August and September — the males are the most numerous. Whether these seasonal differences are of any real significance has yet to be proved, the present observations not being sufficient to enable us to form an opinion.

Length of the life of the moth. — The pink bollworm moth is, or appears to be, what may be described as a nervous species, which makes it rather difficult to keep and handle in captivity. In spite of the difficulties,

Table XXIX.

Proportion of the Sexes.

Week ending.	Total number of moths which emerged.	Number of females.	Per cent of total.	Number of males.	Per cent of total.
1913.					
November 30	245	153	62.4	92	37.6
December 7	625	370	59.2	255	40.8
— 14	515	262	50.8	253	49.2
— 21	328	154	46.9	174	53.1
— 28	368	194	52.7	174	47.3
1914.					
January 4	139	77	55.4	62	44.6
— 11	61	32	52.4	29	47.6
— 18	29	19	65.5	10	34.5
— 25	2	0	0	2	100
February 1	"	"	"	"	"
No more moths until April 12.			"	"	"
April 12	2	2	100	0	0
— 19	1	0	0	1	100
— 26	3	1	33.3	2	66.7
May 3	1	0	0	1	100
— 10	5	3	60	2	40
— 17	0	0	0	0	0
— 24	2	1	50	1	50
— 31	0	0	0	0	0
June 7	3	1	33.3	2	66.7
— 14	0	0	0	0	0
— 21	6	4	66.6	2	33.4
— 28	30	15	50	15	50
July 5	55	33	60	22	40
— 12	129	58	45	71	55
— 19	293	161	54.9	132	45.1
— 26	285	140	49.1	145	50.9
August 2	544	249	45.7	295	54.3
— 9	626	279	44.5	347	55.5
— 16	555	220	39.6	335	60.4
— 23	486	191	39.3	295	60.7
— 30	485	202	41.6	283	58.4
September 6	1,010	414	40.9	596	59.1
— 13	499	221	44.2	278	55.8
— 20	623	267	42.8	356	57.2
— 27	356	165	46.3	191	53.7
October 4	210	98	46.6	112	53.4
— 11	53	32	60.3	21	39.7
— 18	43	25	58.1	18	41.9
— 25	25	21	84	4	16

Table XXIX. (*contd*).

Proportion of the Sexes.

Week ending.	Total number of moths which emerged.	Number of females.	Per cent of total.	Number of males.	Per cent of total.
1914.					
November 1	5	3	60	2	40
— 8	5	2	40	3	60
— 15	1	1	100	0	0
— 22	4	2	50	2	50
— 29	3	2	66.6	1	33.4
December 6	1	1	100	0	0
— 13	1	0	0	1	100
— 20	0	0	0	0	0
— 27	1	1	100	0	0
1915.					
January 3	1	1	100	0	0
— 10	0	0	0	0	0
— 17	0	0	0	0	0
— 24	2	2	100	0	0
— 31	2	1	50	1	50
February 7	2	0	0	2	100
— 14	0	0	0	0	0
— 21	1	1	100	0	0
— 28	0	0	0	0	0
March 7	0	0	0	0	0
— 14	0	0	0	0	0
— 21	0	0	0	0	0
— 28	0	0	0	0	0
April 4	0	0	0	0	0
— 11	2	1	50	1	50
— 18	4	2	50	2	50
— 25	10	6	60	4	40
May 2	16	9	56.2	7	43.8
— 9	26	19	73	7	27
— 16	20	12	60	8	40
— 23	47	25	53.1	22	46.9
— 30	48	27	56.2	21	43.8
June 6	60	22	36.6	38	63.4
— 13	53	23	43.4	30	56.6
— 20	50	20	40	30	60
— 27	45	20	44.4	25	55.6
July 4	19	8	42.1	11	57.9
— 11	19	8	42.1	11	57.9
— 18	26	11	42.3	15	57.7
— 25	17	7	41.1	10	58.9

Table XXX.

Proportion of the Sexes per Month.

MONTH.	TOTAL NUMBER OF MOTHS WHICH EMERGED.	NUMBER OF FEMALES.	PER CENT OF TOTAL.	NUMBER OF MALES.	PER CENT OF TOTAL.
1913.					
November	245	153	62.4	92	37.6
December	1,941	1,027	52.9	914	47.1
1914.					
January	137	59	43	56	40.8
February	0	0	0	0	0
March	0	0	0	0	0
April	6	3	50	3	50
May	8	4	50	4	50
June	59	29	49.1	30	50.9
July	1,123	557	49.5	566	50.5
August	2,536	1,062	41.8	1,474	58.2
September	2,411	1,040	43.1	1,371	56.9
October	236	131	55.5	102	43.2
November	14	7	50	7	50
December	5	4	80	1	20
1915.					
January	4	3	75	1	25
February	3	1	33.3	2	66.7
March	0	0	0	0	0
April	22	12	54.5	10	45.5
May	159	90	56.6	69	43.4
June	207	87	42	120	58
July	78	32	41	46	59
Totals	9,194	4,301	46.7	4,868	52.9

however, a moth has been kept alive for over a month — 31 days to be precise — and no trouble has been experienced in keeping them in cages for about a fortnight. Curiously enough the longest lived specimen received no nourishment of any kind and reference to Table XXXI shows that a number of unfed moths lived as long as or longer than moths which were fed. But on the whole, feeding with sugar syrup, honey and water or even plain water conduces to their well being. The life of the moth is an important fact for us to know : for instance if we wish to trace the probable fate of moths originating from larvæ sown in cotton seed and emerging in March and April — that is at a time when the plants are not yet in a suitable stage for the females to lay eggs on them — we must know as near as possible the limits of the life of the adult. For this reason more detailed experiments will have to be conducted to ascertain, not only the influence of food and water, but also the effect of fertilisation by the male on the duration of life and the effect of the presence or absence of suitable of food plants on impregnated and unimpregnated female moths. It is of importance to know also if in the absence of suitable food plants the sexes mate and whether, if union takes place, the ova develop and have to be laid anywhere — or whether the female can abstain from laying under these circumstances until suitable conditions prevail for oviposition.

DO THE MOTHS EVER HIBERNATE OR ÆSTIVATE?

So far all attempts to keep moths alive in the winter in a hibernating condition have failed. For the purpose of this trial a number of moths of both sexes were placed in a large breeding cage, provided with suitable hiding places such as lumps of earth, dry grass, sacking, etc. The cage was kept in the out-of-doors insectary. All the moths had died before the end of January.

In connexion with this question, the letter received from Osman Effendi Abaza and quoted on page 114 is of interest, since it appears that the moths issuing in great numbers in the seed stores when the temperature

Table XXXI.

Length of the Life of the Moth.

Moth emerged night of	Found dead.	Number of days lived.	Sex.	Nature of food provided.	Nature of food plant provided.	Situation.
1913.						
May 10.....	May 24.....	13	"	Sugar syrup.	Garden Hibiscus.	Outside insectarium.
June 11.....	Alive June 24 escaped..	13	"	Honey.	— —	— —
— 17.....	June 26.....	8	"	None.	— —	— —
— 10.....	July 5.....	24	"	Water.	— —	In laboratory.
— 10.....	— 2.....	21	"	Honey.	— —	—
July 19.....	— 26.....	6	"	None.	— —	—
— 19.....	— 27.....	7	"	—	— —	—
— 20.....	— 26.....	5	"	Water.	— —	—
— 20.....	— 27.....	6	"	—	— —	—
— 20.....	Alive August 4 escaped..	15	"	—	— —	—
October 19.....	November 12.....	23	Female.	None.	—	Outside insectarium.
— 25.....	— 10.....	15	—	—	— —	— —
— 28.....	— 10.....	12	—	—	— —	— —
November 4...	November 23.....	18	"	—	— —	— —
— 11...	December 13.....	31	"	—	— —	— —
September 28..	October 8.....	9	Female.	Sugar syrup.	Cotton.	— —
— 28..	— 10.....	11	—	—	—	— —

September 28..	October 8.....	9	Female.	Sugar syrup.	Cotton.	Outside insectarium.		
— 28..	— 11.....	12	—	—	—	—	—	
— 28..	— 11.....	12	—	—	—	—	—	
— 28..	— 10.....	11	Male.	—	—	—	—	
— 28..	— 10.....	11	—	—	—	—	—	
— 28..	— 10.....	11	—	—	—	—	—	
— 28..	— 14.....	15	—	—	—	—	—	
— 28..	— 14.....	15	—	—	—	—	—	
September 28..	October 6.....	7	"	Water.	—	—	—	
— 28..	— 10.....	11	Male.	—	—	—	—	
— 28..	— 15.....	16	—	—	—	—	—	
— 28..	— 25.....	26	Female.	—	—	—	—	
— 28..	— 14.....	15	"	—	—	—	—	
— 28..	— 14.....	15	"	—	—	—	—	
— 28..	— 14.....	15	"	—	—	—	—	
— 28..	— 14.....	15	"	—	—	—	—	
— 28..	— 17.....	18	"	—	—	—	—	
September 28..	October 5.....	6	"	None.	—	—	—	
— 28..	— 6.....	7	"	—	—	—	—	
— 28..	— 7.....	8	"	—	—	—	—	
— 28..	— 7.....	8	"	—	—	—	—	
— 28..	— 8.....	9	"	—	—	—	—	
— 28..	— 10.....	11	Female.	—	—	—	—	
— 28..	— 10.....	11	Male.	—	—	—	—	
— 28..	— 20.....	21	Female.	—	—	—	—	

had commenced to drop and the food supply to become scarce, all died and showed no tendency to live through the winter in the excellent quarters available in a store filled with sacks of cotton seed. Seed stores have been examined during the winter and early spring but no live moths were observed.

With regard to æstivation we have already stated that moths have been kept alive for as long as a month without food, but the majority die much sooner with or without food. Maxwell-Lefroy [26] would appear to think that the moths may possibly be able to wait a considerable time during the hot weather until their food plants are available. But supposing this is the case it does not really signify true æstivation which is a definite period of repose unbroken by intermittent search for food plants. Taking into consideration the fact that moths commence to breed as early as the middle of May if food plants are available, and it is the larval stage which æstivates, it seems improbale that the adults ever go into this state in Egypt.

DO THE MOTHS EVER LAY EGGS ON GINNED COTTON SEED OR THE OLD BOLLS?

Attempts to induce moths to oviposit on either cotton seed or the old bollworm-damaged bolls have failed. That they ever do so under natural conditions would seem highly improbable as there is no evidence to show that this species feeds on dead vegetable matter. If it did so, it would become a debris feeder or scavenger such as *Pyroderces gossypiella* (*vide infra*), but the known habits of the species all point to the contrary and to its being a feeder only on the green or unripe parts of the food plants.

Young pink bollworms have never been observed feeding in ginned cotton seed of which large quantities have been examined.

DURATION OF THE LIFE-CYCLE.

The duration of the life-cycle is the time it takes the insect to pass through its immature stages of egg, larva, and pupa. This will depend on the time of year, heat accelerating and cold retarding the development of the different instars. So far we have but few complete records for the life-cycle of the pink bollworm, but we know the period is short during the summer months and much prolonged in the late autumn and in winter.

Table XXXII.

DURATION OF THE LIFE-CYCLE.

EGG LAID NIGHT OF	EGG HATCHED.	DURATION OF EGG STAGE.	LARVA LEFT BOLL TO PUPATE.	DURATION OF LARVAL STAGE.	MOTH EMERGED FROM PUPA NIGHT OF	DURATION OF PUPAL STAGE.	TOTAL DURATION OF LIFE-CYCLE.
June 17...	June 24 a. m.	6 days.	July 7.....	13 days.	July 14...	8 days.	27 days.
August 30.	Sept. 4 —	4 —	Sept. 16....	12 —	Sept. 26..	11 —	27 —
— 30.	— 4 —	4 —	— 19....	15 —	— 28..	10 —	29 —
Sept. 1...	— 6 —	4 —	— 25....	19 —	Oct. 7....	13 —	36 —
— 1...	— 6 —	4 —	— 25....	19 —	— 9....	15 —	38 —

Table XXXII shows that from June to October it only takes about a month for the insect to pass from the egg to the adult or moth stage. Possibly further observations may show that there is more variation in the length of the life-cycle than is shown by the above records.

SEASONAL HISTORY.

PROGRESS OF THE ATTACK IN INFESTED FIELDS.

The emergence curve (Plate II) shows that moths of *G. gossypiella* may emerge from infested cotton bolls during December and continue to do so until about the middle of January. So far as we know at present

these moths may continue to breed if food plants on which they can oviposit are available for their offspring. Eggs have been found on cotton (grown as a perennial) as late as the second week in January, and also immature larvæ feeding in unripe bolls. Pink bollworms have further been observed feeding in bamia pods quite at the end of January. However, active breeding at this time of the year most probably seldom takes place owing to the great scarcity of suitable food plants, all cotton, teel and bamia* having been removed from the field by December 31st and the great bulk of the plants long before this date. Generally speaking, it may be said that the normal manner for this pest to pass the winter, or not so much the winter as the period when food plants are wanting or extremely rare, is the resting larval stage. How the larvæ behave when they reach full growth in January and February has yet to be found out — perhaps they go into the resting state or perhaps they pupate and give rise to the adult or moth after a pupal period consistent with the prevailing temperatures**.

Experiments showed that from January 21st to April 12th there was a period of complete quiescence, no moths emerging. In the field, however, it is by no means improbable that in some cases moths might occur as early as the end of March, originating from larvæ sown with the tagawi cotton seed — the subsequent watering of the latter tending to cause the resting larvæ to prematurely leave the resting larval state, come to the surface and there pupate. As regards the fate of moths issuing in the spring time there seems no reason to suppose otherwise than that those lucky enough to find food plants in a sufficiently advanced stage to support pink bollworms (which, it must be remembered, can only live in the buds, bolls and seed pods of bamia, teel, hollyhock and cotton,

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* This applies to these plants as crops, single plants of all three and even small plots of bamia are left about here, there, and everywhere.

** Larvæ found in the seed pods of bamia in January, on reaching full-growth passed into the resting stage. From one larva a moth was obtained April 221, 915. Other larvæ died subsequent to this date.

and not on the leaves, except for a very brief period) oviposit and successfully give rise to offspring. Cotton will not be available as a food plant before the middle of June, except in cases where plants have been grown as perennials or perhaps in Upper Egypt; the same may be said of the teel which is planted at the same time as cotton and more or less keeps pace with it. Thus life for the early moths must be decidedly precarious as the only food likely to be available would be here and there a patch of bamia plants that in spite of the law had been grown as perennials, in order to obtain an early supply of pods and the consequent high market price for this vegetable prevailing in the spring. Presumably those moths which find no food plants perish without giving rise to descendants, but we cannot be certain of this until we know more about the length of life in this stage : supposing under favourable circumstances the moths are long lived no doubt a certain number will survive until the cotton is in a stage to support their young. This, generally speaking, will be about the middle of June, and it is at this period we believe the attack on cotton to commence, the pink bollworms feeding in the larger «squares» or flower buds and in the flowers. The numbers of the pest at this time are exceedingly small and it is only careful search which will reveal its presence in a field.

Table XXXIII shows the progress of the infestation by pink bollworm in a field of cotton at Bahtim in 1914. By the end of June only 0.4 per cent of the squares and 0.2 per cent of the flowers contained pink bollworms. Towards the end of July green bolls were available and about 6 per cent of these were attacked. By the middle of August the attack had increased to 11 per cent in the case of the bolls and that for the flowers was much about the same. Neither the flowers nor the squares appear to be much attacked by this species, for as late as the middle of October 1913 2,000 squares from a very badly infested field showed only 0.9 per cent harboured a pink bollworm. After the middle of August the severity of the attack seems to suddenly increase enormously and from 11 per cent we find that on September 19th the percentage of attacked bolls had risen to 92; and by October 6th the 100 per cent had been reached.

Table XXXIII.

Progress of Attack in Infested Fields.

DATE.	SQUARES.					FLOWERS.					GREEN BOLLS.					RIPE BOLLS 1st PICKING.					RIPE BOLLS 2nd PICKING.				
	TOTAL NUMBER OF BOLLS EXAMINED.	SOUND.	PER CENT.	ATTACKED BY PINK BOLLWORM.	PER CENT.	TOTAL NUMBER OF BOLLS EXAMINED.	SOUND.	PER CENT.	ATTACKED BY PINK BOLLWORM.	PER CENT.	TOTAL NUMBER OF BOLLS EXAMINED.	SOUND.	PER CENT.	ATTACKED BY PINK BOLLWORM.	PER CENT.	TOTAL NUMBER OF BOLLS EXAMINED.	SOUND.	PER CENT.	ATTACKED BY PINK BOLLWORM.	PER CENT.	TOTAL NUMBER OF BOLLS EXAMINED.	SOUND.	PER CENT.	ATTACKED BY PINK BOLLWORM.	PER CENT.
1914.																									
June 30....	500	498	99.6	2	0.4	500	499	99.8	1	0.2															
July 23.....						500	499	99.8	1	0.2	500	470	94	30	6										
August 17...						500	498	99.6	2	0.4	500	445	89	55	11										
September 19.											250	20	8	230	92	3,060	1,338	43.72	1,722	56.28	325	22	6.7	303	93.3
October 6...											250	0	0	250	100										

The following curve (Fig. 2) illustrates this point in a striking manner.

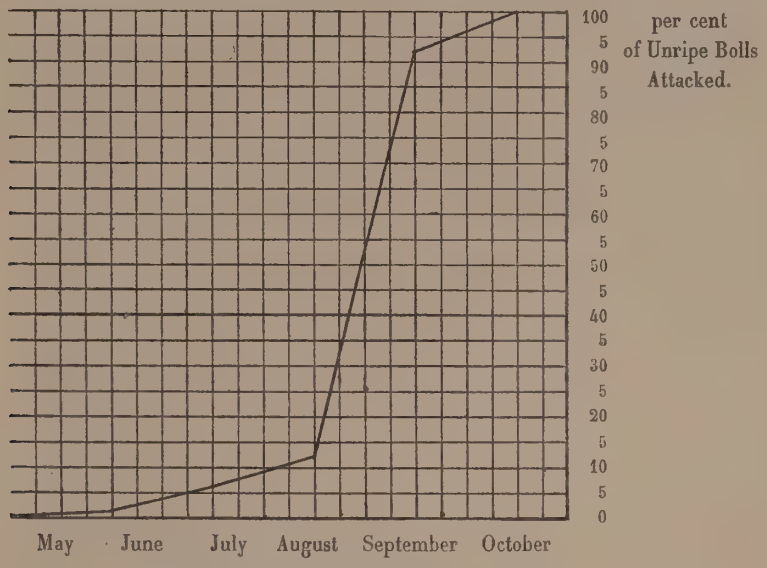

Fig. 2. — Monthly progress of the pink bollworm attack.

It is interesting to know that the period of the great increase in the severity of the attack coincides with the period of the greatest emergence of moths from the resting larvæ — see Plate II — but whether, as we have said before, this is of real significance or not has yet to be ascertained.

As early as September some larvæ commence to go into the resting stage, but at this season the majority still pupate and give rise to moths. In October and November the number of larvæ entering the resting stage is large and the number of active larvæ and moths in the field becomes smaller and smaller.

THE NUMBER OF GENERATIONS OR BROODS DURING THE YEAR.

This is a subject on which little can be said at present owing to the lack of sufficient information on a number of points having an important bearing on it. However, knowing as we do, that in the summer

the life-cycle of the insect from egg to moth takes only about a month or six weeks to be accomplished, it follows that a pair of moths emerging, say in April and finding food plants might, if breeding is continuous, give rise to as many as five generations or perhaps even more before the end of the year. On the other hand moths emerging in October and November would be perhaps but single brooded. In all cases, regarding the number of generations arising from any one pair of individuals, everything will depend on the date when the resting larval stage commences and whether or not the whole or part, or none, of the immediate offspring of a female enter this stage.

THE PROPORTION OF LARVÆ OF DIFFERENT AGES PRESENT IN A COTTON FIELD ON THE SAME DATE.

During the examination of very large numbers of unripe cotton bolls from many localities and obtained at varying dates, one has been struck by the fact that, generally speaking, the greater proportion of larvæ found appear to be from three-quarters to about full-grown. This state of affairs, however, is decidedly more noticeable in the early than during the later stages of the pink bollworm attack. Unfortunately no records of the size of the larvæ found in the green bolls were kept in 1912 and 1913, but in 1914 this was done and the results are shown in the following Table XXXIV.

Although at present these figures may have little significance, perhaps when similar records have been kept for a series of years they may be of value in helping us to trace the number of broods of this pest in the field and also to a knowledge of the main bollworm attack — that is to say, whether it is due to the progressive increase of the few moths emerging in the spring from the bolls of the previous crop and the sowing of infested tagawi seed, or to the attack of the immediate offspring

and subsequent descendents of moths emerging at the commencement of the great activity period of the pest in July and August.

Table XXXIV.

The Number of Pink Bollworms of Approximately the same Age present in Cotton Fields at the same Date.

LOCALITY.	DATE.	NUMBER OF ATTACKED BOLLS EXAMINED.	TOTAL NUMBER OF PINK BOLLWORMS FOUND.	NUMBER OF VERY SMALL TO SMALL LARVÆ FOUND.	PER CENT OF TOTAL LARVÆ.	NUMBER OF $\frac{1}{8}$ TO $\frac{1}{4}$ GROWN LARVÆ FOUND.	PER CENT OF TOTAL LARVÆ.	NUMBER OF $\frac{3}{4}$ TO FULL GROWN LARVÆ FOUND.	PER CENT OF TOTAL LARVÆ.
Bahtim	July 25	30	23	"	"	3	13	20	87
—	August 17.....	54	25	4	16	9	36	12	48
—	September 12..	1,496	1,505	349	23.2	253	16.8	902	60
—	— 19..	230	474	219	46.2	81	17	174	36.8
Damanhour	— 8..	109	93	32	34.4	20	21.5	41	44.1
Dessouk	— 9..	129	97	30	30.9	17	17.5	50	51.6
Batanoun	— 7..	160	180	63	35	35	19.5	82	45.5
Mit Ghamr	— 9..	131	147	74	50.3	15	10.2	58	39.5
Zagazig	— 8..	112	154	77	50	32	20.7	45	29.3
Wasta	— 9..	111	129	49	38	17	13	63	49
Ibshaway	— 8..	33	32	14	43.8	1	3.1	17	53.1
Minia	— 21..	99	120	29	24	9	7.5	82	68.5
Bahtim	October 6.....	289	502	144	28.7	98	19.5	260	51.8
Ghezira	— 27.....	99	234	18	7.7	28	12	188	80.3

THE NUMBER OF PINK BOLLWORMS IN A FEDDAN OF COTTON.

From the figures obtained from the detailed examination of the bolls taken from 204 plants at Bahtim at the time of the 1st picking (September 12th 1914) we can gain some idea — if only an approximate one — of the enormous number of pink bollworms that may be present in a

feddan of cotton. This number or bollworm population will of course vary enormously according to the time of the year : in mid-September it would be nearing the maximum.

From 204 plants a total of 4,487 first picking bolls were removed :

In 3,060 ripe bolls there were 330 pink bollworms.

In 1,427 unripe or green bolls there were 1,498 pink bollworms.

Total Bollworms in the bolls of 204 plants = 1,828.

Supposing these plants to be representative as regards the number of bolls and degree of the attack, the number of pink bollworms present in the bolls of one feddan of such plants would be

$$\frac{1,828 \times 24,000 \text{ plants.}}{204} = 215,058 \textit{ Pink Bollworms.}$$

Even this large figure does not include those larvæ pupating on the ground, nor still in the egg stage or just hatched, nor again the moths, numbers of which were present.

Supposing all the two hundred thousand odd larvæ produced moths we should have at or towards the end of September or early October a moth population of about 44 moths per square yard of ground, and at dusk in walking through a field so thickly inhabited we should be walking through a perfect cloud of moths. Fortunately however, this is never actually the case, and as a matter of fact one does not see a vast number of moths flying about at night amongst the plants in a field which is heavily infested with the pest. Thus it seems evident that a very great mortality occurs somewhere in the life of the pest and as it appears to be rare to find a dead bollworm in a boll, this mortality probably takes place chiefly after the larvæ have matured and left the bolls — whilst they are seeking a situation in which to pupate, during the pupal stage and again when they are moths.

Of the total larvæ present during September in a field of cotton there will of course be a big proportion of resting larvæ which will not give rise to moths the same year.

THE RESTING STAGE OF THE PINK BOLLWORM.

Definition. — One of the most interesting and at the same time most important phases, from the practical point of view, in the life-history of this pest is the ability possessed by certain of the larvæ of passing a period of quiescence of varying length in a fully fed state. For the sake of convenience I have termed this period of rest the «resting period» or «resting stage» and the larvæ which behave in this manner «resting larvæ».

The purpose and nature of the resting stage. — The purpose of the resting larvæ in the economy of the pink bollworm would appear to be a means of ensuring the continuity of the species by enabling it to pass over, in a stage most advantageous to itself, a critical period when in its original natural habitat conditions are, owing to meteorological causes, quite unsuitable for its active breeding.

Since we know that many of the larvæ commence to «rest» whilst the temperature is still high and a suitable food supply available and abundant, and furthermore that they may remain in this dormant condition for from six or eight months to almost two years before pupating and giving rise to the final or moth stage of their life, it would seem that the period of quiescence has nothing in the nature of hibernation about it.

Hibernation is a period of dormancy during the winter and it is passed in various stages by different insects. It is brought about by the actual lowness of the temperature numbing their activity or rendering them, if exposed, liable to death by freezing; arresting their growth in some particular stage; or again, inhibiting active breeding owing to the lack of their host plant, which is not available in the condition to furnish them with food at this season.

The reverse of hibernation is æstivation which, entomologically speaking, is a period of rest forced upon insects in hot climates, or certain areas in hot climates, where during certain months of the year, owing

to lack of moisture in the soil consequent on there being no rain, their food plants, etc. do not exist in a suitable stage to afford them food.

Insects may æstivate in different stages and for a varying length of time. In the case of butterflies and moths hot periods are generally passed in the fully fed larval state. In Egypt we have a number of insects which æstivate : for example, *Hypera variabilis*[27] and *Sitones lineata*[28] two weevils pass the summer as adults in a dormant state. Lady-bird beetles may go into a state of semi-æstivation during the hot months. A sawfly, *Cephus tabidus*[29] may pass one or two summers in the larval stage, but no food is taken during the whole of this long period. Amongst the Lepidoptera we find *Agrotis ypsilon*[30] and *Agrotis nili*[31] may pass the summer in the larval stage, full-fed and dormant.

The pink bollworm's period of rest would appear to be in the nature of æstivation and enables it to pass over a long period when its food plant or plants are not available. From the readiness with which the resting pink bollworms respond to the change from very dry to very moist or wet conditions at high temperatures, it seems not improbable that the agency controlling the supply of their food plants is largely a question of rain, and that their quiescent period is in the main referable to a rainless period in the original habitat of this insect. The gradual emergence of moths from the resting larvæ and the ability some of the latter possess of remaining almost two years in this state, although all are apparently subjected to the same conditions, must be of the greatest advantage to the species as regards its continuity since it is conceivable that, supposing a failure, partial failure or even a serious retardation of the rainy period in its original home, the species might have died out owing to lack of food or to the food plant not having reached a suitable stage of growth, if all the moths emerged at one time and independently of the moist conditions caused by rain. Rain would of course bring about the growth of the necessary plants and parts thereof which furnish food for this insect.

Why some larvæ remain in the resting stage for six months only, others for eight and nine months and yet others for almost two years,

when all are apparently subjected to identically the same meteorological conditions is a problem that yet remains to be solved. One can only suppose that individual larvæ may possess different characteristics, as regards changing to the chrysalis stage, which are perhaps controlled by and respond to different accumulations of temperature at certain degrees of moisture or humidity in the atmosphere.

ADVANTAGE OF THE RESTING PERIOD BEING PASSED IN THE LARVAL STAGE. — A brief examination of this subject will serve to show that the larval stage is the most advantageous for the dormant or resting stage to be passed during a hot and rainless period.

The egg being a minute object with a very thin shell, it is evident that it could not stand high temperatures combined with dryness over a long period. Furthermore, the eggs are not firmly attached to the surface on which they are laid and would thus be liable to become detached (on the leaves, stems etc. of the food plant drying up and shrinking) and blown away to quite unsuitable surroundings.

As regards the pupa stage it is a well known fact that the pupæ of moths and butterflies cannot stand dryness for any length of time — they die under such conditions. Another point also is that the pupa stage of the pink bollworm is not mobile — a decided disadvantage, since in a country where rain comes at a definite period, suddenly and very heavily, it is not improbable that many pupæ might be buried by being washed into cracks etc. and covered with soil : this might happen even supposing the pupa was inside a boll lying on the surface. From such positions the moths would not be able to escape.

To turn to the moth stage : the pink bollworm moth is a small delicate insect and does not seem suited to pass over long hot and dry periods. It is of course mobile and can change its hiding place at will, but in flight and at rest it will be open to the attacks of natural enemies because it is quite incapable of constructing any protection either against them or against high temperatures.

Now as to the larval stage in which the resting stage is passed. In the

first place the larva is fully fed when it enters on this condition and thus has not to concern itself further with the obtaining of food. Its chief advantage, however, lies in its ability to construct a closely woven cocoon of silk within the protection of a seed or seeds which in the case of cotton may be protected by a covering of fibre and this again by the shell of the boll. By this means the larva is not only defended from the attacks of many natural enemies but it must also be much less subject to the effect of high temperatures since it is more or less insulated. Secondly the larva is mobile and when ready to change to the pupa stage can leave the seed or boll, which may have been buried, and form a fresh cocoon in a situation from which the moth will be able to escape without difficulty.

Behaviour of the larva which is going to enter the resting stage. — If a pink bollworm is going to rest it remains in the great majority of cases, so far as we know at present, in the boll in which it has been feeding. Here it spins a densely woven cocoon of tough white silk in the interior of a single hollowed out cotton seed or between two seeds the cocoon being partly in one and partly in the other, the two being firmly held together in this manner, thus giving rise to the so-called « double seeds » (Plate IV, Fig. 15). In these cases it is often only the smaller portion of the cocoon which is spun into the second seed, but sometimes it may be fairly equally divided between the two, the larva thus resting partly in one and partly in the other. The density of the silken lining, which is closely applied to the walls of the seed or the cavity in the seed, varies somewhat and occasionally it seems wanting altogether, only enough silk being spun to close the entrance or exit hole in the seed-coat. Inside its cocoon the larva remains in a curled position head to tail. When the resting cocoon is made in Bamia or Teel seed-capsules it may be formed in a single seed in exeptional cases, but generally speaking it is spun between several seeds (Plate IV, Figs. 14, 17, 18) which are attached to it.

Date when the resting stage commences. — Some larvæ may enter the

resting state as early as the first or second week in September, that is at a date when suitable food plants are still very abundant and both the day and night temperatures are still high; but quite possibly they do so at an even earlier date, since so far our observations on this point have commenced in September only. The number of larvæ entering the resting stage early in September and October is small in comparison with those which pupate and give rise to moths in the course of a few days. In November and December conditions are reversed and it is the resting larvæ which become the most numerous.

THE PROPORTION OF RESTING PINK BOLLWORMS IN «DOUBLE» AND IN SINGLE COTTON SEEDS.

Some persons are under the impression that the resting pink bollworms are found only in the «double seeds» (Plate IV, Fig. 15) and not in the single seeds or at all events only rarely in the latter. That this idea is entirely erroneous is demonstrated by the figures in Table XXXV which show that in a sample of seed by far the greater number of resting larvæ are spun up in single and not double seeds.

To detect the presence of a pink bollworm in a single seed is not always particularly easy unless the seed is cut open or crushed with a light hammer on an iron-plate. However, a careful examination with a good hand lens will generally reveal, in the case of an infested seed, a small round hole in the seed coat spun over with silk or a small protuberance of silk and debris on the side of the seed.

THE BEHAVIOUR OF THE RESTING PINK BOLLWORMS WHEN READY TO TRANSFORM TO THE PUPA STAGE.

The behaviour of the resting pink bollworms when they are ready to abandon this and change to the pupal stage is both of interest and importance, since it would seem that the successful emergence of the moth will depend largely on the sensibility of the larva as regards the suitability of

Table XXXV.

The Number of Resting Pink Bollworms in Double and in Single Cotton Seeds.

Number of sample.	Kind and quality of seed.	Total number of seeds in sample examined.	Number of "double seeds" in sample.	Number of live pink bollworms in double seeds.	Number of single injured seeds in sample.	Number of live pink bollworms in single seeds.	Total number of resting pink bollworms found.	Per cent of resting larvæ in "double seeds".	Per cent of resting larvæ in single seeds.
1	Afifi I. quality.....	5,073	11	10	694	91	101	9.9	90.1
2	— II. —	5,350	76	56	1,564	258	314	17.8	82.2
3	— III. —	5,471	40	33	1,515	312	345	9.5	90.5
4	Joannovitch I. quality.....	4,417	7	4	419	91	95	4.2	95.8
5	— II. —	5,016	13	11	1,148	134	145	7.5	92.5
6	— III. —	5,085	41	25	2,340	120	145	17.2	82.8
7	Voltos I. quality	5,912	17	9	1,826	99	108	8.3	91.7
8	— II. —	5,084	17	11	1,808	225	236	4.6	95.4
9	— III. —	5,347	47	37	2,219	325	362	10.2	89.8
10	Nubari I. quality.....	4,604	5	5	590	82	87	5.7	94.3
11	— II. —	5,489	36	26	1,539	281	307	8.4	91.6
12	— III. —	5,415	68	43	2,489	241	284	15.1	84.9
12	Totals.....	62,263	378	270	18,151	2,259	2,529	10.6	89.4

its surroundings for pupation. For example, suppose a resting pink bollworm to be in a boll which is buried some centimetres below the surface: now, if this larva were to pupate *in situ* it would as a moth most probably be unable to make its escape through the soil, at all events in a perfect condition and capable of flight.

Whether or not the larva actually and consciously possesses the necessary sensibility to provide for its escape when it has reached the moth stage we do not know, but possibly to guard against such accidents as the above there appears to be a strongly developed tendency or instinct on the part of *Gelechia* to change its quarters at this period of its life. If a larva is in a seed or a boll buried in the ground it may make its way to the surface before constructing a cocoon in which to pupate. But similarly larvæ in bolls or seeds lying freely exposed will also shift their quarters. This change becomes necessary in many cases irrespective of the position of the boll, seed, etc., solely on account of another factor : the resting cocoon may be very small compelling the occupant to assume a closely curled position therein, but to pupate the body must be kept straight and hence the reason for the construction of a fresh cocoon of the right dimensions. However, removals and fresh constructions are by no means the rule, since pink bollworms may pupate *in situ* in the same cocoon and in the same situation in which the resting stage has been passed. This may even, as we know from laboratory observation, occur below ground, but whether this often takes place under quite natural conditions is at present not known.

The experiments with infested cotton seed and cotton bolls buried in the soil (pages 165-169) show that the larvæ in a large number of cases make their way to the surface to pupate. But the following observations demonstrate that it is not necessary for seed or bolls to be buried in order to cause the pink bollworm, about to assume the pupal stage, to leave its original quarters before doing so.

In 1913, one hundred «double cotton seeds» were kept under observation to ascertain the number of pink bollworms which would pupate in or outside the seeds. Subsequently it was ascertained that these seeds

contained 57 pink bollworms and of these, 31 left the seeds, and 26 remained in them. Of the former, 14 constructed fresh cocoons and pupated and 17 died before they pupated, owing chiefly to the attacks of the mite *Pediculoides ventricosus*. Of those larvæ which remained in the seeds, 6 pupated *in situ*, that is in the same cocoons in which they had passed the resting stage, and the remaining 20 larvæ died.

In the case of 194 bolls kept under observation the resting pink bollworms at the expiration of their quiescent period behaved as follows :—

47 larve left the seeds and formed a cocoon amongst the fibre remaining in the bolls; 20 left the bolls and formed a cocoon in another situation and 83 pupated *in situ*.

From the above it would appear that the behaviour of the pink bollworms previous to pupation is by no means uniform nor does it seem by any means evident that the sensibility of the larvæ as to the facilities for the escape of the future moth will be sufficiently accute to prevent the latter being buried alive in many cases.

SITUATIONS IN WHICH THE PINK BOLLWORM PASSES THE RESTING STAGE.

From the practical point of view, that is to say, as regards the control of this pest, the question of the situations in which the resting pink bollworms pass over the period between one cotton crop and the succeeding one is of the utmost importance. It has been stated already that the great majority if not all of these larvæ remain under natural conditions in the bolls in which they have fed, spinning cocoons either in the cotton seeds or amongst the matted locks of damaged fibre. Thus it follows that the bolls which remain on the plants after the last picking of fibre has been taken will be, in years such as 1912, 1913, and 1914, heavily infested with the pest. Hitherto and still to a great extent, owing to special circumstances already mentioned, the cotton plants are pulled up with large numbers of both green and dried-up damaged bolls still attached. These plants are then made up into heaps in the field or stored

away on the house tops in the villages to be sooner or later used up as fuel. *All such collections of sticks which remain after April form centres for re-infection and thus are a grave danger to the new crop.*

In addition to the bolls which are left on the cotton sticks, many others harbouring the pest are broken off at the time when the different pickings of the lint are collected and again when the plants are finally removed. Bolls are also broken off by wind action. Of those which reach the ground some will remain on the surface, others will be ploughed into the soil, their disposal depending a good deal on the particular crop following cotton. The fate of the resting larvæ in the bolls which fall to the ground and the extent to which they are a danger to the next crop of cotton will be discussed in due course. Table XXXVI shows the results of the examination of various samples of dead bolls which have been examined at different seasons and from various situations.

It will be seen that the damaged bolls of the 1912 crop examined in February and March of 1913 showed a percentage of bolls infested with live pink bollworms in the resting stage ranging from five to more than twenty. In the case of the 1913 crop, samples from the Society's Farm at Bahtim, near Cairo, the percentage was as high as sixty five and in every 100 infested bolls as many as 100 larvæ could be found. However, the most interesting and important fact demonstrated by this table is that in July and August of 1913 it was possible to find numbers of living pink bollworms. At this season we know that the pest is actively changing from the resting larval to the pupal stage and subsequently when the moths emerge they fly off to the nearest cotton to lay their eggs and thus repeat the serious injury of the previous year. As regards the re-infection of the new crop from the remains of the previous one the following observations recorded in an article to the *Egyptian Gazette*, October 25th 1913, by Mr. Lang Anderson of the Aboukir Land C°, are of great interest and importance. He says :—

« . . . . From November till June we could always find in these unopened bolls the pink bollworm of various sizes and of active vitality.

« We find now that the worst attacked plots are those immediately adjoining and to the

Table XXXVI.

Number of Resting Pink Bollworms found in Dead Bolls on Cotton Sticks of Previous Crop.

LOCALITY.	DATES BOLLS RECEIVED.	SITUATION OF STORED COTTON STICKS.	NUMBER OF BOLLS EXAMINED.	NUMBER OF BOLLS INFESTED WITH LIVE PINK BOLLWORMS.	PERCENTAGE OF INFESTED BOLLS.	TOTAL NUMBER OF LIVE PINK BOLLWORMS IN SAMPLE.
	1913.					
Behera Province :						
Manshiet Mehanna	February 18	?	380	42	11	64
Samokhrat	— 20	?	120	6	5	6
Tewefikieh	— 20	?	120	27	22	27
Safieh	March 3	?	230	50	21	55
Sahali	— 3	?	480	100	20	113
Teh-el-Barud	April 22	Roof of house.	110	17	15	26
Ramsis	— 22	?	230	17	7	20
Delingat	July 27	?	16	6	37	8
Tewefikieh	— 27	?	20	7	35	10
— (Mihna)	— 27	?	20	2	10	2
Damanhour	— 29	?	30	1	3	1
—	— 29	?	26	1	3	1
Toud	— 30	?	17	1	5	1
Damanhour	September 22	Roof of house.	50	0	0	0
Gharbia Province :						
Sakha	March 25	On the soil in a field of beans.	130	12	9	15
—	May 19	Heap of cotton sticks in field.	280	0	0	0
—	— 19	In field ?	290	6	2	10
Kafr-el-Zayat	July 28	?	7	0	0	0
Mehallet Menouf	— 28	Heap of cotton sticks in field.	140	5	3.5	5
Kafr-el-Zayat	— 30	Roof of house.	20	3	15	3
Korachieh	— 30	Heap of sticks in field.	60	3	5	3
Mehalla el-Koubra	— 31	— — —	100	4	4	4
Bassioun	August 4	?	50	12	24	12
Santa	— 9	?	100	1	1	1

Dakahlia Province :						
Aga	July 28	?	27	3	11	3
Sharkia Province :						
Bilbeis	July 28	?	20	1	5	1
Fakous	— 28	?	15	1	6	2
Diarb Nigm	— 31	?	50	0	0	0
Mashtoul	— 31	?	48	0	0	0
Hehia	August 5	?	100	3	3	3
Zagazig	— 6	?	100	0	0	0
Menoufia Province :						
Samadoun	July 27	Roof of house.	32	1	3	1
Batanoun	— 31	?	60	1	1.5	1
—	August 4	Roof of house.	60	0	0	0
Menouf	— 5	— - —	100	1	1	1
Ashmoun	— 7	?	100	4	4	5
Tala	— 18	?	98	0	0	0
Kouesna	September 16	Heap of cotton sticks in field.	192	4	2	4
Kalubia Province :						
Kalioub	July 27	?	10	0	0	0
Mit Bereh	— 27	?	25	2	8	2
Shibin el-Kanater	— 30	?	40	0	0	0
Toukh	August 7	?	70	0	0	0
Upper Egypt :						
Fayoum	August 28	?	30	0	0	0
Minia	— 18	?	100	0	0	0
Beni Suef	— 29	?	29	0	0	0
Biba	— 30	?	48	0	0	0
Ossem Gizeh	September 7	?	27	1	3.5	2
Abu Kerkas	— 7	?	100	0	0	0
Kalubia Province :	1914.					
Bahtim	December 28	Heap of sticks in field.	250	164	65	256

Table XXXVII.

The Number of Resting Pink Bollworms

DATE WHEN SAMPLES EXAMINED.	SEASONS 1912-1913—1913-1914. VARIETY AND QUALITY OF SEED.	PLACE OF ORIGIN.	WEIGHT OF SAMPLE EXAMINED.	NUMBER OF SEEDS IN SAMPLE.	NUMBER OF SEEDS INFESTED LIVE PINK BOLLWORMS.	PER CENT OF INFESTED SEED.
			Grams.			
1913.						
22 March	Afifi — tagawi	Sakha.	550	4,437	0	0
30 —	— —	?	500	5,236	12	0.22
27 —	— for export	?	500	5,183	28	0.54
5 April	— —	?	500	6,015	319	5.00
15 July	— —	?	50	484	2	0.4
14 —	— —	?	50	550	19	3.45
13 —	— —	?	50	500	27	5.40
3 April	— —	?	500	5,817	160	2.75
22 March	Jannovitch — tagawi	Hemrowi.	500	5,248	8	0.15
8 April	— —	?	250	2,387	0	0.00
15 May	— I. quality	Shabrarees.	500	4,700	7	0.14
17 —	— II. —	—	500	5,200	29	0.55
22 March	Sakellarides — tagawi	Sakha.	500	4,608	8	0.17
8 April	— —	?	250	2,305	0	0.00
9 —	Assili — tagawi	?	250	2,228	0	0.00
9 —	Abbassi — tagawi	?	250	2,415	2	0.08
18 May	— III. quality	Abou Samada.	500	5,100	62	1.21
19 —	— Fuss	— —	500	4,700	320	6.80
9 April	Nubari — tagawi	?	250	2,284	1	0.04
4 May	— I. quality	Aga district.	500	5,000	11	0.22
4 —	— II. —	»	500	5,250	30	0.57
10 —	— III. —	»	500	5,650	76	1.34
12 —	— IV. —	»	500	6,000	140	2.33
1914.						
28 January	Afifi — tagawi	Bishbish.	500	5,000	31	0.62
1 February	— —	—	500	5,100	18	0.35
14 —	— for export	?	500	5,400	130	2.4
15 —	— —	?	500	5,000	150	3.0
29 January	Jannovitch I. and II. picking	Sakha.	500	5,300	84	1.60
27 January	Sakellarides I. and II. —	—	500	4,850	37	0.76

IN DIFFERENT SAMPLES OF COTTON SEED.

DATE WHEN SAMPLES EXAMINED.	SEASONS 1913-1914—1914-1915. VARIETY AND QUALITY OF SEED.	PLACE OF ORIGIN.	WEIGHT OF SAMPLE EXAMINED.	NUMBER OF SEEDS IN SAMPLE.	NUMBER OF SEEDS INFESTED LIVE PINK BOLLWORMS.	PER CENT OF INFESTED SEED.
1914.			Grams.			
2 February	Sakellarides I. and II. picking.	Sakha.	500	5,100	125	2.45
1 —	— — —	Bishbish.	500	5,000	16	0.32
3 —	— I. picking.....	Bahtim.	500	4,700	38	0.80
22 —	— Tagawi.....	?	100	940	11	1.17
22 —	— —	?	100	1,060	20	1.88
2 March	— —	Mansoura.	100	1,060	7	0.66
2 —	— —	—	100	1,040	6	0.57
2 —	— —	—	100	970	8	0.82
3 —	— —	Kafr-el-Zayat.	100	960	8	0.83
3 —	— —	—	100	960	10	1.04
3 —	— —	—	100	980	9	0.91
3 —	— —	—	100	1,070	15	1.40
3 —	— —	—	100	1,050	7	0.66
3 —	— —	—	100	1,040	9	0.86
3 —	— —	—	100	950	7	0.73
3 —	— —	—	100	960	6	0.62
7 —	" " "	Tookh.	100	890	4	0.45
7 —	" " "	—	100	980	4	0.40
7 —	" " "	—	100	1,020	7	0.68
1915.						
3 March	Afifi I. quality.....	Mehalla Kebir.	500	5,073	101	2.0
3 —	— II. —	—	500	5,350	314	5.86
3 —	— III. —	—	500	5,471	345	6.30
9 —	Jannovitch I. quality.....	—	500	4,417	95	2.15
9 —	— II. —	—	500	5,016	145	2.89
9 —	— III. —	—	500	5,085	145	2.85
11 —	Nubari I. quality.....	—	500	4,604	87	1.9
11 —	— II. —	—	500	5,489	307	5.60
11 —	— III. —	—	500	5,415	284	5.25

south of Ezbehs, and this leads to the conclusion that the moths hatched out from the Ezbeh heaps of cotton sticks, and were blown by the northerly breeze to the nearest cotton.»

It is evident that the destruction of all the dead and green bolls at the end of the season is an *essential* step in the control of this pest.

The second place in which the resting stage of the pink bollworm abounds is in the ginned cotton seed, and since the resting stage commences before any fibre has been picked, we find the pest both in the best quality or tagawi seed, used for sowing the new crop, and also in the lower grades of seed chiefly used for crushing in order to extract the oil. The bulk of this seed is exported, but a large amount is retained in Egypt to be crushed at local oil mills.

The resting pink bollworms, being safely housed inside the seed, pass through the ginning process, by which the seed is separated from the fibre, in very large numbers without in any way being disturbed or injured. At present we do not know the total mortality amongst this pest which arises from mechanical injury during the ginning; most probably it is quite small only those larvæ (as we have already remarked) which are free or have spun cocoons amongst the fibre and not within the security of a seed being crushed in the passage through the gin.

Table XXXVII shows the results of the examination of various samples of cotton seed. The degree to which cotton seed is injured and also the degree to which it harbours resting pink bollworms is likely to vary considerably. It will depend a great deal on the picking from which the seed originated; and not improbably also to the variety of cotton — early, medium or late maturing; and yet again, to the locality — Northern or Middle Lower Egypt, or Upper Egypt.

To what extent the resting or potential resting larvæ may leave the seed-cotton or the ginned seed when they are in store and spin their cocoons in cracks in the floor or walls of the stores, has yet to be ascertained, since it is important to know if stores and ginning factories may act as centres of re-infection irrespective of any stocks of seed, or seed-cotton used for cleaning the gins before commencing operations the following season, which may remain in them until April or later.

We now have to consider the possibility of the resting stage being passed in situations other than those mentioned above.

DO THE LARVÆ UNDER NATURAL CONDITIONS EVER LEAVE THE BOLLS TO PASS THE RESTING STAGE IN OTHER SITUATIONS?

If considered from the point of view of control this question at once becomes important, since if it does occur and is at all a common habit the destruction of those resting pink bollworms we can get at by burning all the remaining bolls left after the last picking; and furthermore, by treating the infested seed, may possibly tend to be less effective as a preventive measure than otherwise would be the case.

Laboratory observations show apparently that the resting larvæ may behave in this manner, but until these have been confirmed or disproved by direct field evidence it is impossible to give either a positive or a negative answer to the question.

The observations made in the laboratory with regard to this subject were as follows :—

500 unripe cotton bolls collected at Sakha, Gharbia Province, in November 1913 were each placed in a transparent paper bag (Lot A) which was securely closed. Half of these bolls were kept in the laboratory and the other half (Lot B) out of doors.

The 250 bolls kept in the laboratory contained, as was subsequently ascertained, at the end of November 304 living pink bollworms nearly all of which were «resting larvæ». Of this number, 25 or 8.2 per cent left the bolls between the end of the month and December 7th and spun cocoons in the paper bags; 22 of these larvæ remained in the larval stage until the following spring when they were destroyed by the attacks of the predaceous mite *Pediculoides ventricosus*, Newpt.; the other 3 larvæ were not resting larvæ but pupated in December and subsequently gave rise to the moth or perfect insect in January 1914.

Now why did certain of the resting larvæ abandon the bolls on reaching full growth and not others? Apparently it was not owing to the bolls becoming wet and rotten inside, thus forming an unsuitable habitation, since as a matter of fact the bolls did not rot but dried up fairly normally in the bag. Moreover, in seven out of the twenty five cases one or more larvæ remained in the bolls to pass through the resting stage. Furthermore, the other 270 odd pink bollworms remained as resting larvæ in the bolls until the following summer. Thus so far as one can tell the larvæ left the bolls on completing their growth of their own will and not because the state of the boll compelled them to do so.

In the case of the 250 bolls kept outside, 15 larvæ had left by 7th December and passed the resting stage spun up in cocoons in the bags. What proportion of the total was represented by this 15 we do not know as the bolls were invaded by ants which are believed to have devoured many of the larvæ. Presumably the number would be much about the same in the two lots, so one may say that about 4.5 per cent of the resting larvæ in Lot B left the bolls on reaching maturity and passed this stage in another situation.

If the pest behaves in a similar manner under field conditions, and it seems by no means improbable that this may be the case, the chance of those pink bollworms which abandon the security of the bolls to pass the resting stage in other situations until the following June-October period of activity will, like that of those larvæ spun up in the bolls lying on the surface of the ground, be none too good. Their success in this respect would seem to depend chiefly on situation chosen by the larvæ or thrown in their way by chance to pass this phase of their life.

In addition to dead leaves and flowers etc. lying on the ground, one would, if looking for resting pink bollworms in situations other than the bolls, examine the tufts of coarse grass growing on the banks of the irrigation channels and canals frequently forming the boundary of one or more sides of a cotton field and also in the cracks and under lumps of soil on the banks as being likely places to be sought for by a resting larva in which to spin a cocoon.

DURATION OF THE RESTING STAGE.

The work of entomologists in India has shown us already that this species passes considerable periods in the resting stage, but no actual dates or records of the duration of these periods appear to have been given. In 1913 a lot of about 250 dead bolls picked in January from cotton sticks, which had been used for the purpose of «sticking» peas, were kept out of doors in a breeding cage. These revealed to us the fact that pink bollworm moths might emerge from such bolls as late as October, thus giving a period of rest much longer than had been anticipated. In order to obtain more numerous and complete records on this most important question it was decided to conduct operations on a much larger scale by employing 50,000 bolls infested with pink bollworm. These bolls were picked early in November from the cotton growing on the Society's Farm at Bahtim, Choubrah, just before the plants were pulled up.

To accommodate this large number of bolls, a special breeding cage (Plate IX, Fig. 1) was made by adapting a packing case of the necessary dimensions to the purpose. This was filled inside with a series of trays the bottoms of which were formed of wire netting. At one end a «trap» was fitted : this had a series of glass louvres at the back and a large glass door in front; the sides and top were of wood; the bottom was formed by a zinc lined draw to contain water on which a small quantity of paraffin was poured. In front of the glass door an ordinary paraffin oil lamp was placed and lighted each evening. The cage was furnished with a series of ventilation holes and it was kept outside under an open shed.

The temperature and humidity conditions inside the cage were it is considered very similar to those which prevail in the interior of a large heap of cotton sticks. The temperature kept fairly constant, but there was a marked variation in the day and night temperature, the difference being from 10° to 12° F. The atmosphere inside reached saturation point when similar conditions prevailed outside, that is, during the foggy mornings of January and February.

At night the moths being attracted towards the illuminated end of the cage passed through the narrow openings in the glass louvres to the glass door forming the front of the trap and sooner or later fell into the draw containing the water and paraffin. Each morning the number of moths in the draw was counted and their sex determined. From the figures so obtained the curve on Plate II has been constructed.

It is not unlikely that a certain number of moths failed to make their way into the trap immediately after emergence and others perhaps may have found their way back again into the cage without falling into the water, but the probability is that all of these moths were trapped and thus the records are not affected in any serious way by these possibilities.

It was observed that the number of moths emerging each night fluctuated very considerably, but why this is so we do not know any more than the reason or reasons why some moths emerge in April and others not until December.

With reference the great variation in the number of moths emerging each night during the active periods it is perhaps of interest to note that the same fact has been observed in the field in the case of moths caught by lamp traps.

It will be noted that during November and the greater part of December of 1913, a large number of moths issued nightly from the bolls, but towards the end of the year the number fell off very considerably until by the third week in January it ceased altogether. Presumably the majority of the moths which emerged during this period originated from larvæ that reached full growth and pupated at a date subsequent to that on which the bolls were picked and placed in the cage. The pupal stage, owing to low temperature at this time, would be considerably prolonged.

The last moth of the autumn and winter period of activity emerged during the night of January 21st and the next not until April 12th, thus there was a period of absolute quiescence of 81 days or nearly three months.

During April and May very few moths emerged, the total being fourteen only for the two months.

To turn to field records for the moment. It is interesting to note that *Gelechia gossypiella* was taken at night towards the end of April 1914 by Mr. Andres at Heliopolis, near Cairo, and again on the 16th and 19th of May 1914. During this month the species was found in the larval stage in the squares and flowers of cotton growing in the laboratory garden. These plants were grown as perennials and thus formed a source of early food supply for the pest — considerably earlier in fact than would have been the case under normal field conditions.

In June the number of moths emerging from the bolls in the breeding cage rose to 59, showing an increased tendency on the part of the larvæ to leave the resting state and pupate.

In July the great summer active period of the pest may be said to commence. The number of moths recorded this month was 1,123 and in August this number was more than doubled, the figure being 2,536.

During September emergence of moths from resting larvæ continues with equal activity, the number obtained from the cage being 2,411, this figure being almost equal to that of August. In October, however, we find a marked decrease, the number falling to 236. In November the number was 14 and in December only 5 moths emerged. It would thus seem that the period of greatest activity for the change from the resting larva to the adult stage or moth is from July to the end of September after a resting period of from eight to ten months dating from November the first, but some of the larvæ may have commenced to rest earlier than this date, — during October or even in September. The moths emerging in December must have originated from larvæ which had passed at least a year, if not more, in the larval state before pupating, assuming that the length of the pupal stage was normal for the season.

Moths still continued to emerge in 1915; four came out in January and three in February of this year. From the end of February to the 6th of April there was a period of quiescence and then suddenly there was quite a period of activity, 24 moths issuing in April, 159 in May and 207 in June. In 1915, during these three months, a total of 390 moths issued as against 73 during the corresponding period in 1914. It would seem

then that there may be a tendency in the second year for the activity period to occur earlier. But this may have been due possibly to meteorological conditions; in the case of the 1914 seed also, a tendency was noted for the resting larvæ to leave the seeds and pupate as early as March 1915. This was not the case or at least it was not observed to be so in 1914.

In 1915 the first moth of *Gelechia* was captured outside on April 23rd.

In July 1915 only 80, as against 1,123 moths in July 1914, were recorded.

We now know that the pink bollworm may emerge as a moth after a resting period of 20 months and this period is likely to be prolonged as moths are still emerging — August 1915 *. This is a fact of great practical importance, since it shows that it is useless to quarantine seed, cotton fibre, etc. for less than 2 years from date of ginning with a view to preventing the introduction of the pest into new territory. Such a lengthy quarantine period is impracticable.

Cotton sticks kept on the roofs of houses until the second season still remain a danger to the new crop.

As regards the pink bollworm in cotton seed, Mr. H.C. Jefferys of the State Domains, Sakha, informs me that an examination of 600 «double seeds» picked on 12th December 1914 from a sack of 1913 grown seed showed the presence of 17 live larvæ of this species. There is thus no reason to suppose that the length of the resting stage will be less in ginned cotton seed than inside the old bolls.

Moths emerging after a resting period in the larval stage of more than one year are sexually perfect. — It is was thought that perhaps moths which emerged after a resting period of more than one year might not be sexually perfect and capable of laying eggs. However, this is not so, and dissection of moths emerging in 1915 from 1913 larvæ has shown the ovaries of the female and the sexual organs of the male

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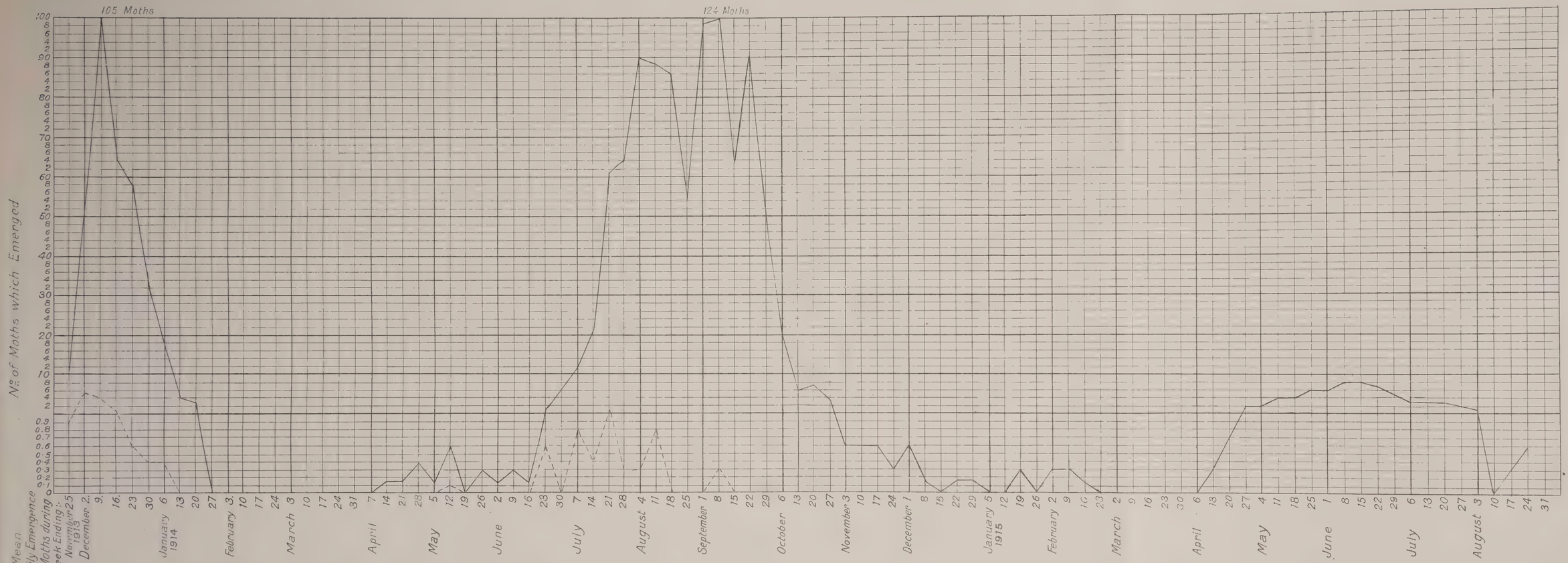
* *Note added November 12th 1915.* — No moths have emerged since August 28th.

EMERGENCE OF PINK BOLLWORM MOTHS & CHELONELLA SULCATA



REFERENCE

———— Emergence of Pink Bollworm Moths during 1913, 1914, 1915, from 50,000 Damaged Cotton Bolls picked from the 1913 Crop at Bahtim in November.

- - - - - - - - Emergence of Chelonella sulcata, a parasite of the Pink Bollworm.

Reproduced at the Survey Dept. Cairo Oct. 1915 (303-46)

are quite normal. The females in many cases contain eggs almost fully developed when they emerge.

THE FATE OF THE RESTING PINK BOLLWORMS IN DAMAGED BOLLS LYING ON THE SURFACE AND BURIED IN THE SOIL, AND THEIR DANGER TO THE NEW CROP.

It has been pointed out already that a large number of the dry and damaged bolls are knocked off during the picking of the fibre, or again when the plants are pulled up, and also by wind action. These bolls will in many cases contain resting pink bollworms, and in the years of severe attack, such as 1913 and 1914, the pink bollworm population lying on the ground beneath the plants for a longer or shorter period as the case may be can but be very considerable. We have to consider therefore, what will be the ultimate fate of these larvæ and whether they constitute a danger to the new crop. This question is still under investigation. At present we are only in possession of sufficient information to indicate what the answer to it is likely to be. Before going into details, however, it is necessary to briefly examine the agricultural practice in vogue after the cotton crop has been picked.

One of four crops may follow cotton, viz.: berseem or Egyptian clover, beans, wheat, or barley. In the case of berseem the seed may be sown from October to November amongst the standing cotton plants, a preliminary watering being given and the seed sown broadcast on the wet soil. When this new crop is sufficiently established, the cotton plants are pulled up. Another method frequently practiced is to remove the cotton plants, split the old ridges with a plough, water and sow. In this case the date of sowing depends on when the plants are removed from the land.

The berseem crop will receive altogether from 8 to 10 waterings before it is finished in May or early June.

In the case of beans grown after cotton, the plants are removed, the land ploughed and the seed is dropped in behind the plough to be covered

by the next furrow turned and finally the land is harrowed. During the time the crop is on the land, it will receive from one to two waterings including the one at sowing time. After harvest — say in April — the land will, generally speaking, remain sheraki, that is in a perfectly dry state until August when the rise of Nile and consequent plentiful supply of water will permit of its being irrigated preparatory to being sown to durra or maize. During the dry season a few weeds may manage to grow for a time, but on the whole one may reckon the surface of the soil and all lying on it will be fully exposed to the rays of the sun without anything in the nature of efficient shade being given.

When wheat or barley follows cotton the land, after it has been cleared of cotton plants in November, will be watered and ploughed, the seed broadcasted on the moist soil and then covered by harrowing or the equivalent operation. In January or February the crop will be irrigated and again in March or the beginning of April. After the harvest in May or June, the land will remain, as in the case of beans, dry until August when the removal of the sheraki restrictions will permit of its being watered and ploughed for a fresh crop.

The above outline of the cultivation of the three crops which may be grown after cotton indicates the treatment to which resting pink bollworms in fallen bolls are likely to be subjected to: Some of them may be buried and all will receive several heavy waterings and will thus, for a longer or shorter period depending on circumstances, be exposed to moist surroundings. Now how will the pink bollworms spun up in their cocoons in the damaged bolls fare under these conditions?

Firstly it is important to note that the Egyptian or native plough turns a shallow furrow only, in fact it breaks up the surface of the ground rather than turns the soil over, so that bolls are not likely to be buried to a greater depth than 10 cm. if as much and many of course are not buried at all, and others only a few centimetres below the surface. Thus during the greater part of the time they will not be in particularly damp surroundings, the first 8-10 cm. of soil being comparatively dry except for a short time after a watering has been given.

As regards the bolls left on the surface and amongst the crop, some remain intact, others gradually get broken up and the hard locks of fibre distributed over the ground. In some cases it is possible to find quite a lot of loose fibre on the surface — amongst beans for example — this will have come from the broken up bolls and some of it may perhaps have fallen from the cotton plants and not been picked up.

No attempt has yet been made to estimate the number of fallen bolls, but when one considers there may be from 20,000 to 26,000 plants per feddan, it is evident that if only a few bolls fall from each plant the number on or in the soil must be very large*.

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* Counts made in two fields of the dead bolls lying on the soil beneath the plants gave the following results :—

Field A. On 48 square metres found 1,480 dead bolls
= 129,500 to the feddan
= approximately 5.4 per plant or 10.8 per nogra.

Field B. On 70 square metres found 1,660 dead bolls
= 99,600 to the feddan
= approximately 4 per plant or 8 per nogra.

In both fields the cotton plants were still standing so after the plants had been pulled up the number of bolls lying on the soil would be still greater. The bolls were of average to small size. The following figures show the number of bolls damaged by bollworm and the number of living pink bollworms found.

Field A. N° of dead bolls = 1,480.
N° damaged by bollworm = 1,480 = 100 %.
N° of living pink bollworms = 261.
N° of bolls infested with live pink bollworms = 215 bolls = 14.5 % of total bolls (1,480).

Field B. N° of dead bolls = 1,660.
N° damaged by bollworm = 1,660 = 100 %.
N° of living pink bollworms = 710.
N° of bolls infested with live pink bollworms = 478 = 28.8 % of total bolls (1,660).

The bolls which are knocked off when the plants are pulled up are likely to be the most heavily infested with resting pink bollworms. This, however, will depend a good deal on the date when the plants are removed.

Now as to the fate of resting pink bollworms in these bolls. We will first give the only field observations we have relating to this subject. Reference to Table XXXVI (pages 144-145) shows that at the end of March 130 bolls picked up in a field of beans at Sakha, Gharbia Province., contained 15 live pink bollworms; and furthermore, a quantity of 230 grms. of loose seed-cotton from the same field harboured four live *Gelechia* larvæ.

In this instance it is quite evident that the larvæ had not been affected to any serious extent by the cultural operations after cotton nor by the watering. After March 23rd they would not have been further disturbed by watering and would only have had the harvesting of the crop to pass through, an operation involving but slight risks to the pink bollworms in the bolls, etc. What then will be the factors, if any, which will be likely to prevent the resting larvæ surviving until the activity period of the species commences in July and August, at which time they would normally transform to pupæ and subsequently the moth stage?

As a matter of fact it is after the crop has been harvested that the most critical and fatal period arrives for the resting pink bollworms; the land being practically bare the bolls are exposed to the full heat of the sun and will be raised to a temperature which will be sufficiently high, it is believed, to kill the pest even when it is in the interior of a damaged boll.

In order to obtain information on this point, a number of bolls were exposed to the sun from November 1913 to the end of June 1914 in the laboratory garden, on the roof of the laboratory, and on the roof of the insectarium situated in the garden. The roof of the latter was formed of wire gauze and so the bolls in this case were under decidedly different conditions as regards temperature to those lying on dry soil and on the cement roof of the laboratory. All positions received the full sun light for the greater part of the day.

All the bolls used for this work were picked in November from the Society's Farm at Bahtim, Chubra, and were heavily infested with resting pink bollworms. Several thousands of these bolls were spread in a thin

layer in their respective positions on November 20th 1913. The plot of ground on which Lot III bolls were placed received a heavy watering on November 20th, on December 28th and again on March 3rd 1914. All the other bolls were kept dry.

With regard to the controls : through an oversight sufficient bolls were not kept back to permit of an examination of a check lot to correspond with each sample from the exposed bolls. This, however, is no great disadvantage, for as will be seen the mortality in the laboratory from January to May was slight. For the last check lot — that examined on June 25th — a different sample of bolls had to be used (still from Bahtim but from a different field) owing to the original supply having been used up for previous examinations. When samples were taken from the bolls exposed outside, the plot was roughly divided up into squares and several bolls taken from each. Labour available at the time did not permit very large numbers of bolls being examined.

The figures in Table XXXVIII speak for themselves. Up to the middle of February the mortality amongst the pink bollworms in the bolls kept outside was comparatively insignificant, but by the end of the first week of April it had, with the exception of the roof lots IV and V, almost reached 100 per cent. In the case of lot IV, D. on the roof of the laboratory, the bolls were in a thicker layer than on the soil which were in a single layer; the increased protection thus afforded accounts for the much larger number of live larvæ found on April 8th. Similarly lot V, E. on the roof of the insectarium were spread more thickly than those on the ground and moreover, being on wire gauze some 8 feet from the ground temperature conditions would be different to those on the soil, hence the 40 per cent of live larvæ at the end of June when all the other lots showed 100 per cent dead larvæ.

These figures most certainly show that the chance of resting pink bollworms surviving in the bolls fully exposed to sun on the surface of dry sheraki land in May, June and July is a remote one.

As regards this question of the effect of sun heat on the resting pink bollworms in exposed bolls the following temperature records and remarks

Table XXXVIII.

Effect of Exposure to Sun Heat on Resting Pink Bollworms in Dead Bolls.

Date of Examination of Samples.	Lot N° 1. A. Several thousand bolls exposed to sun from November 1913 to June 1914. Bolls placed on surface of soil in laboratory garden. *Bolls not watered.*						A°. Bolls kept in laboratory as a control on A.					
	Number of bolls examined.	Total number of pink bollworms found.	Number of live pink bollworms.	Per cent of total.	Number of dead pink bollworms.	Per cent of total.	Number of bolls examined.	Total number of pink bollworms found.	Number of live pink bollworms.	Per cent of total.	Number of dead pink bollworms.	Per cent of total.
6 January 1914....	»	»	»	»	»	»	80	90	88	97	2	3
10 February 1914...	50	64	42	65.5	22	34.5	»	»	»	»	»	»
8 April 1914.....	50	45	3	7	42	93	»	»	»	»	»	»
3 May 1914.....	50	42	6	14	36	86	55	63	58	92	5	8
25 June 1914.....	50	31	0	0	31	100	50	56	48	86	8	14

Date of Examination of Samples.	Lot N° II. B. Several thousand bolls exposed to the sun from November 1913 to June 1914. Bolls were placed on surface of soil in laboratory garden. *Bolls not watered.*						B^{b}. Bolls kept in laboratory as a control on B.					
6 January 1914....	»	»	»	»	»	»	60	55	53	96	2	4
10 February 1914...	50	50	40	80	10	20	»	»	»	»	»	»
8 April 1914.....	50	51	1	2	50	98	»	»	»	»	»	»
3 May 1914.....	50	27	1	4	26	96	50	23	23	100	0	0
25 June 1914.....	50	20	0	0	20	100	50	56	48	86	8	14

Lot N° III.

DATE OF EXAMINATION OF SAMPLES.	C. SEVERAL THOUSAND BOLLS EXPOSED TO THE SUN FROM NOVEMBER 1913 TO JUNE 1914. BOLLS WERE PLACED ON SURFACE OF SOIL IN LABORATORY GARDEN. *BOLLS WATERED PERIODICALLY.*						C°. BOLLS KEPT IN LABORATORY AS A CONTROL ON C.					
6 January 1914....	»	»	»	»	»	»	80	90	88	97	2	3
10 February 1914...	50	78	69	88.5	9	11.5	»	»	»	»	»	»
8 April 1914.....	50	51	0	0	51	100	»	»	»	»	»	»
3 May 1914.....	»	»	»	»	»	»	50	63	58	92	5	8
25 June 1914.....	50	35	0	0	35	100	50	56	48	86	8	14

Lot N° IV.

DATE OF EXAMINATION OF SAMPLES.	D. SEVERAL THOUSAND BOLLS EXPOSED TO SUN ON ROOF OF LABORATORY FROM NOVEMBER 1913 TO JUNE 1914.						D°. BOLLS KEPT IN LABORATORY AS A CONTROL ON D.					
6 January 1914....	»	»	»	»	»	»	130	147	140	95	7	5
10 February 1914...	50	60	48	80	12	20	»	»	»	»	»	»
8 April 1914.....	50	77	41	53.25	36	46.75	»	»	»	»	»	»
3 May 1914	50	53	0	0	53	100	50	78	75	96	3	4
23 June 1914.....	50	46	0	0	46	100	50	56	48	96	8	14

Lot N° V.

DATE OF EXAMINATION OF SAMPLES.	E. SEVERAL THOUSAND BOLLS EXPOSED TO SUN ON ROOF OF INSECTARIUM FROM NOVEMBER 1913 TO JUNE 1914.						E°. BOLLS KEPT IN LABORATORY AS A CONTROL ON E.					
6 January 1914....	»	»	»	»	»	»	130	147	140	95	7	5
10 February 1914...	50	83	69	83.13	14	16.87	»	»	»	»	»	»
8 April 1914.....	50	84	56	66	28	34	»	»	»	»	»	»
3 May 1914.....	50	65	30	46	35	54	50	78	75	96	3	4
25 June 1914.....	50	40	16	40	24	60	50	56	48	86	8	14

will be of interest. For them I am indebted to the Physical Service, Ministry of Public Works.

Absolute maximum Temperature recorded during February to June 1914.

	FEBRUARY.	MARCH.	APRIL.	MAY.	JUNE.
	Shade temp. at Giza (° C.).				
Maximum reading...	31.5	31.0	32.5	41.8	44.1
Date.....	27th	28th	18th	31st	1st
	Sun temp. at Helwân between 1h.40m and 2h p. m. (° C.).				
Maximum reading :					
Bright bulb.....	42.4	44.5	41.2	54.5	54.1
Black bulb.....	59.4	63.3	58.5	71.2	69.5
Date	27th	24th	11th	31st	1st

« The black and bright bulb temperatures are taken in vacuo and are higher than they would be in air, as convection and conduction are eliminated. »

« Without actual experiments it is impossible to say what the temperature of a cotton-boll lying in the ground would be, but it would probably be somewhere near the temperature of the bright bulb. If lying in the sun it would probably receive more heat than the bright bulb, but would lose more by conduction and convection. »

It is possible, however, that in the north of the Delta the larvæ may survive under such conditions to a later date than they would in the neighbourhood of Cairo for instance and also further south, but even in the north I think that the sun heat of June and July will be sufficient to raise bolls lying on the surface of dry land to a temperature fatal to the pink bollworm. The fatal temperature for this species is from 50° to 55° C.

A sample of 290 bolls — see Table XXXVI — received from Sakha on May 19th bearing a label « dead bolls from field » contained 31 pink

bollworm larvæ of which 10 were alive. Unfortunately we do not know whether these bolls were picked up off the naked ground, from amongst a crop, or even possibly from a heap of sticks in the field. The latter seems unlikely since an accompanying sample of 280 bolls was labelled «from Kom el Hatab» (heap of sticks). In this lot only 7 larvæ were found all of which were dead. One would have expected that these results would have been exactly the reverse, that is to say, the bolls from the field would have shown the absence of living pink bollworms; it is thus possible that some confusion took place in the labelling of the two samples. However, in any case the figures are not of much value owing to the doubt about their origin and history, but if the sample in which ten live larvæ were found really came from the bare soil, the occurrence is of great importance as showing the survival of the pest to so late a date in dead bolls lying on the ground. This result of course differs slightly from our own figures for exposed bolls which, examined May 3rd, showed a complete or almost complete absence of living larvæ.

One point must not be lost sight of, — that in spite of the great improbability of resting larvæ surviving in fallen bolls exposed to the sun until the real activity period of the pest commences in the latter part of June or early July, there is still the possibility, or rather one may say likelihood, of a certain number of larvæ abandoning the resting stage in March to transform to pupæ and subsequently moths which would emerge in April. The numbers behaving in this manner, however, are likely to be very small and the danger to be apprehended from moths issuing in April is still problematical depending as it does, on whether or not they can live without ovipositing until the cotton is in a sufficiently advanced stage to support their offspring. At present we know the moth may live a month in captivity, but whether this period may be greatly exceeded under natural conditions has yet to be ascertained. If moths coming out in April found bamia or some other food-plant at hand on which they could lay their eggs, the case of course would be altered, but this vegetable will be rare, practically speaking, at this season. Conditions will also be rather different according to locality, cotton «squaring» and flowering earlier

in the south than in the north, but against this will be the fact that fatal temperatures on the soil will in all probability be reached earlier in Upper than in Lower Egypt.

As regards infested bolls lying on the surface of the soil occupied by wheat, barley or bersim. In the case of the two former crops conditions are about the same as what they would be if the land was growing beans (except that the cereals will give rather more shade) and no doubt the fate of the pink bollworm will be the same. When, however, berseem follows cotton, conditions are different, for not only are waterings comparatively frequent which will tend to rot and thus cause the break up of the bolls much more quickly, but this crop is generally fed off by cattle tethered in the field and so the bolls will also be subjected to a fairly close trampling. It would thus seem that the chance of the pink bollworms surviving in bolls on the surface and subsequently giving rise to moths is even more remote in the case of berseem than in either the wheat or the bean crops.

We now have to consider the fate of the pink bollworms in the bolls which are buried during the ploughing of the land to prepare it for the crop following cotton. In this case conditions are different for the bolls and any resting pink bollworms they harbour will be under wet conditions for a longer period, or so long as the surrounding soil keeps wet; but this in the light of preliminary experiments carried out in the laboratory does not seem to be materially disadvantageous to the pest. As regards advantages : pink bollworms will be protected from possible natural enemies and it also seems probable that they will receive a great protection from sun-heat owing to the intervening layer of soil. The degree of the protection so afforded will of course depend on the thickness of this layer which, it must be remembered, will be hard, compact, and almost bone-dry from say April to August in the case of beans and wheat; and from the end of May to August when berseem has been the crop grown after cotton. It will thus be in a condition to readily absorb and conduct heat.

At present we have no information as to the soil temperatures at

depths varying from 5 cm. to 15 cm. in sheraki land during the summer months, nor have we any record of bolls buried at such depths during the hot season, but it is hoped to obtain the necessary data on this subject during the coming summer.

As regards the effect of moisture and dryness on *Gelechia* larvæ in bolls buried beneath the soil several experiments have been made the results of which are given in the curves on Plate III.

For this work 500 damaged bolls were buried at a depth of about 8 to 10 cm. in each of nine wooden boxes with wire gauze lids.

An examination of a sample of these bolls made on January 25th 1914 showed that 250 bolls contained 367 pink bollworms of which :—

356 or 97 per cent were alive
6 or 1.6 per cent were dead — cause unknown
5 or 1.4 per cent had been killed by *P. ventricosus* — a predaceous mite.

Thus supposing this sample to have been fairly representative of the particular lot of bolls (from Society's Farm, November 1913) from which the boxes were filled, there should have been from 600 to 700 live larvæ in each box. As a matter of fact nothing approaching this number of larvæ emerged. The mortality from the mite *P. ventricosus* was probably high since the bolls touched each other so that the progress of the active mites from boll to boll would not have been prevented by any intervening barrier of soil. It is possible also that some larvæ managed to escape from the boxes owing to the lids not fitting quite tightly.

Boxes Nos. I to IX were treated as follows :—

No. I. Box filled with bolls November 24th 1913, covered to depth 8-10 cm. with just moist soil, kept in Laboratory until December 1st 1913 and then removed to out-of-doors Insectarium and heavily watered. Subsequently soil kept wet = « Wet Box ».

No. II. As above. Kept in Laboratory until March 14th 1914 and then to Insectarium. Soil was not watered = « Dry Box ».

No. III. As above. Kept in Laboratory until April 11th 1914 as a

« Dry Box », then removed to Insectarium and heavily watered. Subsequently soil kept wet as a « Wet Box ».

No. IV. As above. Kept in Laboratory as a « Dry Box » until June 21st when heavily watered for the first time. Subsequently remained in Laboratory as a « Wet Box ».

No. V. As above. Kept all time in Laboratory as a « Dry Box ».

No. VI. As above. Kept all time in the Laboratory as a « Dry Box ».

No. VII. Filled with bolls November 18th 1913, covered to a depth of 8-10 cm. with just moist soil. Soil heavily watered November 18th. Kept in Laboratory as a « Wet Box ».

No. VIII. Filled with bolls November 18th 1913. Covered depth 8-10 cm. moist soil. Kept in Laboratory as a « Dry Box ».

No. IX. Filled with bolls November 18th. Covered depth 8-10 cm. with just moist soil. Heavily watered November 18th and subsequently kept whole period in Insectarium as a « Wet Box ».

Daily records were kept of the number of pink bollworms emerging from the bolls and appearing at the surface. From these figures the series of curves shown on Plate III have been constructed.

The history of boxes V, VII and VIII (Plate II, Series B) and boxes I, II and IX (Plate II, Series C) is of considerable interest.

In the case of Box VII kept in the laboratory, the effect of the heavy watering is exceedingly marked in comparison with Boxes V and VIII both kept dry in the laboratory. The thorough wetting of the soil caused a comparatively large number of larvæ to emerge, whereas only a few larvæ left the bolls buried in the dry or just moist soil. After the middle of December the number of bollworms emerging from Box VII fell to almost nothing; that from Box V ceased after December 14th and that from Box VIII after the 21st of the month. In Wet Box VII however, the emergence of larvæ actually continued almost without intermission, though in a minor degree only, until the third week in May.

Now let us turn to Boxes I, II, IX (Plate II, Series C). No. IX a wet box was started on the same date and treated in exactly the same manner as Box VII except in the matter of situation, the former being kept outside and thus exposed to the fluctuation between the night and day temperatures; whereas the latter being in the laboratory, was subject to an almost uniform temperature during the 24 hours. As will be seen by the curves, Box IX gave totally different results to Box VII. The only explanation which it appears will account for the difference is a question of temperature. From Box IX only 5 larvæ emerged from the soil in 1913 as against 85 from Box VII, which was kept in the laboratory; after December 14th emergence from the former ceased altogether and was not renewed until March 1914. Box No. I gave practically the same results as No. IX; its treatment was exactly the same except that the bolls were not placed in the Box until November 24th and it was not watered until December 1st when it was placed outside. Unfortunately no «Dry Box» was kept outside from November to March when Box II was removed from the laboratory to the insectarium. However, as a matter of fact, it is probable that the curve for the latter box would have been much the same had it been placed outside in November instead of in March.

The difference between Boxes IX and VII was so marked that in February 1914 it was decided to examine half the bolls from the latter in order to see if all the larvæ were dead, which would have accounted for the great variation in the numbers recorded. Half the contents of Box VII was examined, and as a check half of No. VIII also. The soil was replaced and the previous treatment of the boxes continued as before. The following were the results of the three examinations :—

Box IX. — «Wet Box.» Insectarium. Half the bolls removed for examination 26/II/1914.

Result : Live larvæ found	106
Dead larvæ found	4

Owing to the soft and rotten state of the bolls they mostly broke up and it was impossible to count the number actually removed and examined. It was equally difficult also on account of the condition of the

material to discover the bodies of the dead larvæ. Only four dead larvæ are recorded by Mr. Andres who made the examination, but probably there were more.

Box No. VII. — «Wet Box.» Laboratory. Half of the bolls removed for examination. 26/II/1914.

Result : Live larvæ found..... 106
Dead larvæ found..... 0

Box No. VIII. — «Dry Box.» Laboratory. 200 bolls removed for examination. 27/II/1914.

Result : Live larvæ found..... 241
Dead larvæ found..... 3

In boxes VII and IX the number of live larvæ found was the same and so taking into consideration the number of bollworms which had already reached the surface alive in Box VII it would seem that there had been a much greater mortality in Box IX than in VII, assuming of course that the bolls in each box had been equally badly infested. This, however, is by no means certain as there may be a considerable variation in bolls taken from the same sample if it is a large one, and it would have been better had a sample of bolls been examined from each box at the commencement of the experiment.

In the case of Box No. VIII, a «Dry Box», 241 live larvæ were found in 200 bolls and only 3 dead ones, a result much nearer to that given by the examination of the original check sample.

The results of the examination were important, showing as they did that the emergence did not cease from Box IX and practically so from Box VII after the month of December because there were either no larvæ or only very few left in the bolls as might have been the case, but that it was owing to some other cause prevailing at the time. The most probable explanation would seem to be that the temperature both indoors and out was sufficiently low to keep the pink bollworms almost or entirely inactive in spite of abundant moisture in the soil. In the case of Box VIII — a dry box — there was no movement on the part of the larvæ towards the surface partly on account of the cold and also perhaps to the dry state of their surroundings.

INFLUENCE OF DRY & WET CONDITIONS ON THE EMERGENCE OF PINK BOLLWORMS FROM BOLLS BURIED UNDER 10 CMS. OF SOIL.

52 Larvae

38 Larvae

36 Larvae

Number of Larvae

Week Ending
November 30 1913
December 7
14
21
28
January 4 1914
11
18
25
February 1
8
15
22
March 1
8
15
22
29
April 5
12
19
26
May 3
10
17
24
31
June 7
14
21
28
July 5
12
19
26
August 2
9
16
23
30
September 6
13
20
27
October 4
11
18
25
November 1
8
15

REFERENCE

A.

- - - - - - Box III. Dry in Lab to April 11, then to Outside & Watered.

——— Box IV. Dry in Lab Watered 1st time June 21.

-.-.-.- Box VI. Dry in Lab.

B.

-.-.-.- Box V. Dry. Kept in Lab.

- - - - - - Box VIII. Dry. Kept in Lab.

——— Box VII. Wet Kept in Lab. ½ removed 2·II·1914.

C.

-.-.-.- Box II. Dry. Kept in Lab: to mid March-afterwards Outside.

——— Box I. Wet. Kept Out-of-Doors.

- - - - - - Box IX. Wet. Kept Out-of-Doors ½ removed 2·II·1914.

Reproduced at the Survey Dept. Cairo Oct. 1915 (303-46)

In March a distinct activity was manifest on the part of the larvæ in all the wet boxes — especially No. I, which had not been disturbed.

Emergence from Box IX ceased for good after the end of March, but in the case of the other two — Nos. VIII and I — larvæ continued to appear at the surface until the end of May.

As regards the «Dry Boxes» II, V, VI and VIII, all gave practically the same curves whether kept in the laboratory or outside in the insectarium.

In the case of Box II, in which the survival of larvæ was greatest, the bollworms did not begin to emerge regularly until the beginning of May whereas in the other boxes the movement to the surface began some weeks earlier. In all, however, there was a small sporadic emergence of larvæ in February which is of interest.

If the emergence curve for Box II is compared with the curve showing the emergence of moths from the 50,000 bolls in the large breeding cage, they will be seen to be very similar.

Box No. III is of interest as showing the great influence on the larvæ of watering the dry soil when the temperature is high. Box IV shows a similar, but not quite so marked, increase in the emergence of pink bollworms from the buried bolls after the latter were watered for the first time on June 21st. Box VI gave similar results to Box II.

None of the boxes were exposed to the direct sunshine; the soil, however, became very dry indeed in the Dry Boxes, but the larvæ were apparently well able to support extreme lack of moisture in their surroundings. The soil in the dry boxes was loose and so did not act as a serious obstacle to the larvæ reaching the surface, but under field conditions it is conceivable that the soil might be so compact and hard when dry as to imprison them. This is a point on which exact information is at present lacking. The emergence of larvæ in the «Wet Boxes» shows that they can force their way through very compact soil, but what may have been the mortality — if any — owing to the larvæ dying of exhaustation in their efforts to reach the surface we do not know.

Table XXXIX.

Subsequent History and Behaviour of Pink Bollworms which Emerged from Boxes I-IX

From November 1913 to April 1914.

MONTH.	CONDITIONS LARVÆ KEPT UNDER.	NUMBER OF LARVÆ EMERGING, KEPT UNDER DRY OR MOIST CONDITIONS.	NOVEMBER.			DECEMBER.			JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.		
			NUMBER LARVÆ PUPATING.	NUMBER LARVÆ REMAINING AS LARVÆ.	NUMBER LARVÆ DIED DURING MONTH.	NUMBER LARVÆ PUPATING.	NUMBER LARVÆ REMAINING AS LARVÆ.	NUMBER LARVÆ DIED DURING MONTH.	NUMBER LARVÆ PUPATING.	NUMBER LARVÆ REMAINING AS LARVÆ.	NUMBER LARVÆ DIED DURING MONTH.	NUMBER LARVÆ PUPATING.	NUMBER LARVÆ REMAINING AS LARVÆ.	NUMBER LARVÆ DIED DURING MONTH.	NUMBER LARVÆ PUPATING.	NUMBER LARVÆ REMAINING AS LARVÆ.	NUMBER LARVÆ DIED DURING MONTH.	NUMBER LARVÆ PUPATING.	NUMBER LARVÆ REMAINING AS LARVÆ.	NUMBER LARVÆ DIED DURING MONTH.	NUMBER LARVÆ PUPATING.	NUMBER LARVÆ REMAINING AS LARVÆ.	NUMBER LARVÆ DIED DURING MONTH.
November.	Dry.	41	4	34	3	16	14	4	0	10	4	0	10	0	0	10	0	2	6	2	2	0	4
	Moist.	14	0	0	0	11	2	1	0	1	1	1	0	0	"	"	"	"	"	"	"	"	"
December.	Dry.	40	"	"	"	5	26	9	3	19	4	1	14	4	3	9	2	2	2	5	2	"	"
	Moist.	21	"	"	"	4	4	13	1	1	2	0	1	0	1	0	0	0	0	0	"	"	"
January.	Dry.	2	"	"	"	"	"	"	0	1	0	1	0	0	"	"	"	"	"	"	"	"	"
	Moist.	4	"	"	"	"	"	"	0	4	0	2	0	2	0	"	"	"	"	"	"	"	"
February.	Dry.	10	"	"	"	"	"	"	"	"	"	1	1	8	0	0	1	"	"	"	"	"	"
	Moist.	2	"	"	"	"	"	"	"	"	"	0	1	1	0	0	1	"	"	"	"	"	"
March.	Dry.	4	"	"	"	"	"	"	"	"	"	"	"	"	4	0	0	"	"	"	"	"	"
	Moist.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
April.	Dry.	14	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	9	1	4	1	0	0
	Moist.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"

Before discussing the practical bearing of the observations described above it is first necessary to take note of the subsequent behaviour of the pink bollworms which emerged from the boxes.

Table XXXIX gives the history of some 152 larvæ which left the bolls from November to April 1914. They were kept in tin glass top boxes containing cotton lying on a layer of dry or damp soil. However, these different conditions cannot be said to have had any definite effect such as determining whether a larva should remain as a resting larva or transform almost immediately to the pupa stage. It would seem that many of the pink bollworms which issued from the buried bolls in November and December were not true resting larvæ and therefore the treatment to which they had been subjected was not the cause of their leaving their quarters, but that in reality it was simply a natural movement to the surface which would have occurred under any conditions. Yet as a matter of fact we cannot by any means be certain that this was the case owing to the fact that the treatment may have changed what would have been a resting larva into a larva which pupated at an abnormally early period. Some support is lent to this possibility by the number of larvæ emerging in the wet boxes being so very much larger than that from the dry boxes. However, that this was not so in all cases seems evident from the history of a number of larvæ from Box VII (wet box) and shown in the following Table XL. From this it will be seen that some of the bollworms pupated and some rested as larvæ, but the majority were of the former class.

Another point to be noted is that all the larvæ under observation had to be frequently disturbed in order to be certain what they were doing and this may have further tended to make them behave in an abnormal manner.

A matter of considerable importance in the case of pink bollworms in the wet boxes is that although the bolls were for the most part soft and rotten when examined in February — and probably long before this date — they were still able to remain in them spun up in their almost watertight cocoons during March, April and May.

Table XL.

SUBSEQUENT BEHAVIOUR OF PINK BOLLWORMS WHICH EMERGED FROM BOX VII.

REF. NUMBER OF LARVA.	DATE LARVA EMERGED FROM SOIL.	SUBSEQUENT BEHAVIOUR OF LARVA.	CONDITIONS UNDER WHICH KEPT.
	1913.		
1	November 29...	Pupated — December 7.....	Dry.
2	— 29...	Resting Larva — pupated after middle of April 1914.	Dry.
3	— 29...	— — — —	—
4	— 29...	— — — —	—
5	— 29...	— — — —	—
6	— 29...	— — — —	—
7	— 30...	Pupated — December 9.....	Moist.
8	— 30...	— — 9.....	—
9	— 30...	— — 13.....	—
10	— 30...	— — 13.....	—
11	— 30...	— — 13.....	—
12	— 30...	— — 16.....	—
13	— 30...	Resting Larva — pupated after mid April 1915....	—
14	December 2....	Pupated — December 16.....	Moist.
15	— 3....	— — 13.....	Dry.
16	— 3....	Resting Larva — pupated in May 1915.....	Dry.

Now as regards their practical bearing, these experiments would appear to indicate that if infested cotton bolls are ploughed into the soil and the latter watered shortly afterwards at a season when the mean prevailing temperature is on the low side, such as would be the case when the bulk of wheat, barley, beans, and to a less extent the berseem (which is put in as soon as possible) are sown in most parts of Lower Egypt, a certain number of pink bollworms — though a small proportion of the whole only — are likely to leave the buried bolls and make their way to the surface. They will then spin cocoons in some available shelter and either remain as «resting larvæ» or more probably

change to the pupa stage and in due course give rise to moths. In either case it is unlikely that these larvæ would be of danger to the succeeding cotton crop, since the moths will find food plants scarce or lacking altogether; and the resting larvæ, if they are not destroyed by the trampling of cattle in the case of berseem, will be killed unless they had found well shaded and sheltered positions at the sides of the field by sun-heat in April and May when the wheat or beans have been removed and the bare land exposed. After each watering of the berseem a few larvæ might emerge, following the curve given by Box VII; or more probably towards the end of December and in January and February, the curves of Boxes IX and I. In March there is likely to be an increased movement of bollworms towards the surface and this activity may continue until the end of May. Pink bollworms surviving until the end of April or early May at which period the berseem will receive its last watering, thus putting the soil in a state to facilitate their emergence, may well be a source of danger since moths emerging during May and living from a fortnight to a month or possibly longer would be likely to find the cotton bearing «squares» of a sufficient size to support their offspring.

As regards the wheat, barley, and bean crops which receive only two or three waterings it seems probable that the larvæ in buried bolls are likely to be much less influenced by moisture than they would be under a berseem crop because the first 10 cm. of soil in a wheat, barley or bean field is not likely to be so wet, except for a few days after irrigation : and during the greater part of the time, especially after March, it will be comparatively dry up to this depth. Thus on the whole the curve given by Box II may well indicate what is likely to be the behaviour of bollworms in buried bolls under these conditions. When the land is watered for the maize crop on the removal of the sheraki restrictions we would expect a sudden emergence of larvæ such as was the case in Box IV (Plate III, Series A).

In conclusion there seem to be grounds in the present state of our knowledge for regarding with suspicion buried bolls infested with pink

bollworms, especially in wheat, barley and bean land, as a probable source of re-infection for the new cotton crop — always assuming, however, the following :—

1. The fact of the bolls being below a certain depth of soil will prevent their being raised to a temperature fatal to the resting pink bollworms, presumed to be in the interior spun up in the seeds, by the heat from the sun. Obviously some will not be so protected but others may be, everything depending on the thickness of the overlaying soil. Other factors involded are likely to be the nature and state of the soil and the locality — Upper or Lower Egypt, and in the case of the latter — North or South Delta.

2. That the larvæ will be able to penetrate hard compact soil. This condition does not apply to larvæ surving after the sheraki land has been watered.

3. That the heat of the sun is not sufficient to kill the larvæ after they have reached the surface — either in the larval stage or after they have changed to pupæ, because in the majority of cases they will be forced to pass the pupa on the surface, spinning cocoons under and attached to a lump of earth or other shelter. Some exceptionally lucky bollworms might find their way into weedy and grassy growths at the borders of the field or on the banks of canals, etc., which would afford them great protection from the sun. Whether or not the resting larva escapes being killed at this period of change in its life by the effect of sun heat will depend on the time of its emergence from the soil, both as regards the hour of the day and the mouth of the year. In May and June the midday and early afternoon temperature on the surface of the ground is, if the latter is in a dry condition, sufficient to destroy a pink bollworm attempting to crawl about on it for any length of time. Pupæ under any but very large lumps of soil will also be killed by the sun's heat at this season.

It is evident then that before we can speak definitely of the importance of buried bolls and also of infested seed used for sowing as a

danger to the succeeding cotton crop we must have complete information on the above three points, but more especially as regards dry soil temperatures in the field since practically speaking the whole question of the danger of the infested bolls which fall off the plants depends on this factor. If the first 5 to 10 cm. of soil and its contents which is *sheraki* is raised by sun heat to a temperature fatal to the pink bollworm — viz. 50° C., so much the better for Egypt, since it will simplify very considerably the problem of control*.

THE FATE OF THE RESTING PINK BOLLWORMS SOWN WITH THE TAGAWI COTTON SEED AND THEIR DANGER TO THE NEW CROP.

The cotton crop is sown during the second half of February and in March in Upper Egypt and the Middle Delta and in the North as late as April, that is to say, the crop is planted whilst the pink bollworm is still

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* Note added when in press.

Survival of resting larvæ in buried bolls at depths of 10 and 15 cms. during the summer months.

Extensive records are still lacking, the only observations available at present are given below : these would seem to indicate, however, that it is by no means improbable that resting pink bollworms will escape being destroyed by sun heat in bolls which have been buried by the ploughing to a depth of 10 cm.; above this the line the danger from such bolls will decrease rapidly.

Soil Conditions. — A very light sandy Ghezireh soil. Was lightly watered and trodden, after bolls were buried, to make it compact. Subsequently left dry. Left bare of vegetation. Exposed to full sun shine from about 10 a. m. to 4 p. m.

Resting Larvæ. — Were in « double » cotton seeds, in dead cotton bolls and in the seed capsules of teel.

Lot A buried at 10 cms. depth
Lot B buried at 15 cms. depth } March 10th 1915.

Date of Examinations and Results.

September 30th, 1915.

Lot A. (10 cm.).

In 335 double cotton seeds found 10 dead pink bollworms.

In 68 bolls found *1 living pink bollworm*, 4 dead larvæ and 4 empty pupa cases.

in the resting stage. Reference to Table XLI shows that even in the best tagawi seed (that used for sowing) the percentage of resting larvæ ranges, after a severe attack (1914), from 1.9 % to 2.15 %, which means that sowing at the usual rate of about two and one half kelehs of seed per feddan, we may sow at the same time from 4,000 to 5,000 living pink bollworms in the infested seeds; and if low quality seed is used, this number might easily be about doubled. It is thus evident that the fate of these larvæ is of the utmost practical importance — do they or do they not constitue a danger to the new crop?

Before discussing in detail this important subject it is necessary to explain for the benefit of those who are not conversant with methods of cotton cultivation that the land intended for this crop is put up into ridges running in an east and west direction. The seed is sown in small

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In 37 teel seed-capsules found 7 *living pink bollworms*. 1 recently dead, and 5 dead and dried up.

August 7th, 1915.

Lot B. (15 cm.).

In 250 double seeds found *6 living pink bollworms*, 4 dead, and 1 empty pupa case.

In 130 bolls found *10 living* pink bollworms.

Soil Temperatures. — I have, unfortunately, so far but one record of soil temperatures.

September 3rd. Max shade Temp. = 34° C.

Laboratory garden, in bare, sandy soil, fully exposed to sun. Temp. taken midday.

5 cm. depth = 48.5° C.

10 cm. depth = 39.5° C.

In hard compact soil, fully exposed to sun. Time 12.20 p. m.

5 cm. depth = 49.5° C.

10 cm. depth = 42° C.

We require really to know the temperatures not only of the soil at different depths, say from 5 to 15 cms., but also the temperature reached *inside* the dead cotton bolls buried at different depths and in different types of soil. Better still, would be the temperature in the interior of a hollow single seed or a «double» seed.

In order to obtain this information, I think it will be best to employ a self recording electrical temperature apparatus. By this means we should be able to obtain a continuous record of the temperatures the resting pink bollworms would be subjected to during different months of the year in this particular environment, without any disturbance of the soil, etc., in order to introduce thermometers.

holes or pockets about two thirds of the way up the ridges and is then covered with some 3 cm. to 5 cm. of soil. About ten seeds are planted in each hole, but the plants are subsequently thinned out to two. When sown the field is watered, the soil being thoroughly wetted. A second watering is given from thirty to sixty days after the first, according to locality and the nature of the soil, etc. Between the waterings from one to two hoeings — generally only one — are given to destroy weeds and break up the surface. It is important to note that after a watering the soil between the ridges and on the wetted part of the ridges cracks fairly deeply. The extent of this cracking, however, depends largely on the nature of the soil, whether it is sandy, loamy, or heavy.

We must now consider what the effect of wetting the soil will be on the pink bollworms in the seed, and supposing they are disturbed from their retreats by this treatment whether they will be able to reach the surface, and further what will be their probable procedure on arriving there. In order to obtain some information on the behaviour of resting larvæ in the moist soil and their ability to force their way through it, the following series of trials were first carried out.

EFFECT OF MOISTURE ON RESTING PINK BOLLWORMS IN COTTON SEED SOWN IN WET SOIL AND THEIR ABILITY TO REACH THE SURFACE.

For this experiment 20 grammes of infested cotton seed and 35 «double seeds» were sown on April 16th 1913 in each of 12 boxes which were kept in the laboratory.

The Seed in Box No.		1	was covered with soil to a depth of			1 cm.
—	—	2	—	—	—	2 —
—	—	3	—	—	—	3 —
—	—	4	—	—	—	4 —
—	—	5	—	—	—	6 —
—	—	6	—	—	—	8 —

The soil was then heavily watered (April 16th) but no subsequent watering was given.

Table XLI.

The Number of Resting Pink Bollworms found

DATE.	SEASONS 1912-1913—1913-1914. VARIETY OF SEED.	WEIGHT OF SAMPLE EXAMINED.	APPROXIMATE NUMBER OF SEEDS IN SAMPLE.	NUMBER OF LIVE PINK BOLLWORMS FOUND.	PER CENT INFESTED SEED.	NUMBER OF LIVE PINK BOLLWORMS IN SEED TO SOW 1 FEDDAN.
		Grams.				
1913.						
22 March	Sakellaridis	500	4,608	8	0.17	405
8 April	—	250	2,305	0	0.0	"
9 —	Assili	250	2,228	0	0.0	"
22 March	Jannovitch	500	5,248	8	0.15	405
8 April	—	250	2,387	0	0.0	"
15 May	—	500	4,700	7	0.14	354
9 April	Abbassi	250	2,415	2	0.08	202
7 —	Ashmouni	250	2,697	0	0.0	"
22 March	Afifi	500	4,437	0	0.0	"
30 —	" "	500	5,236	12	0.22	607
9 April	Nubari	250	2,284	1	0.04	101
1913-1914.						
27 January	Sakellaridis	500	4,850	37	0.76	1,873
2 February	—	500	5,000	125	2.5	6,328
2 —	—	500	5,000	16	0.32	810
3 —	—	500	4,700	38	0.80	1,923
22 —	—	100	940	11	1.17	2,784
22 —	—	100	1,060	20	1.88	5,062
2 March	—	100	1,060	7	0.66	1,771
2 —	—	100	1,040	6	0.57	1,518

IN SAMPLES OF TAGAWI COTTON SEED 1912 TO 1914.

DATE.	SEASONS 1913-1914—1914-1915. VARIETY OF SEED.	WEIGHT OF SAMPLE EXAMINED.	APPROXIMATE NUMBER OF SEEDS IN SAMPLE.	NUMBER OF LIVE PINK BOLLWORMS FOUND.	PER CENT INFESTED SEED.	NUMBER OF LIVE PINK BOLLWORMS IN SEED TO SOW 1 FEDDAN.
		Grams.				
1913-1914.						
2 March	Sakellaridis	100	970	8	0.82	2,025
2 —	—	100	960	8	0.83	2,025
3 —	—	100	960	10	1.04	2,531
3 —	—	100	980	9	0.91	2,278
3 —	—	100	1,070	15	1.40	3,796
3 —	—	100	1,050	7	0.66	1,771
3 —	—	100	1,040	9	0.86	2,278
3 —	—	100	950	7	0.73	1,771
3 —	—	100	960	6	0.62	1,518
3 —	—	100	890	4	0.45	1,012
3 —	—	100	980	4	0.40	1,012
3 —	—	100	1,020	7	0.68	1,771
29 January	Jannovitch	500	5,300	84	1.58	4,252
28 —	Afifi	500	5,000	31	0.62	1,569
1 February	—	500	5,100	18	0.35	911
1914-1915.						
9 March	Jannovitch	500	4,417	95	2.15	4,809
3 —	Afifi	500	5,073	101	2.00	5,113
23 February	Nubari	500	4,604	87	1.90	4,404
21 March	Voltos	500	5,912	108	1.82	5,467

Table XLII.

Emergence of Resting Pink Bollworms from Double Seeds sown in Boxes of Soil at Different Depths.

DATE.	BOXES 1 TO 6 SOWN AND WATERED ONCE ONLY ON 16 APRIL 1913. DAILY EMERGENCE OF LARVÆ.						BOXES 7 TO 12 SOWN AND WATERED 16 APRIL 1913, WATERED AGAIN ON 29 APRIL 1913, 11 AND 22 MAY 1913. SOIL ALWAYS WET. DAILY EMERGENCE OF LARVÆ.						CONTROL DRY SEED.
	BOX 1 1 CM.	BOX 2 2 CM.	BOX 3 3 CM.	BOX 4 4 CM.	BOX 5 6 CM.	BOX 6 8 CM.	BOX 7 1 CM.	BOX 8 2 CM.	BOX 9 3 CM.	BOX 10 4 CM.	BOX 11 6 CM.	BOX 12 8 CM.	
19 April	1	1	1				1						0
20 —	1	1		2			1			1			0
21 —	2	2	2	5			3	3	1				0
22 —	3	5		2						2	1	1	0
23 —	1	2		1			1			2	3		0
24 —	1		2	7			1		2	7	3	3	0
25 —	1	2	1	1	1	3				1		1	0
26 —		1							1	1		1	0
27 —		1				2			1		1	1	0
28 —													0
29 —		1				1					3	1	0
30 —							1		1				0
1 May													0
2 —													0
3 —													0

4 —							1		2		1		0
5 —													0
6 —													0
7 —							1						0
8 —													0
9 —													0
10 —													0
11 —													0
12 —													0
13 —													0
14 —													0
15 —													0
16 —													0
17 —													0
18 —													0
19 —													0
20 —													0
21 —									1				0
22 —										2			0
Seeds examined May 28, 1913.	5 Larvæ still in Seeds.	2 Larvæ still in Seeds.	1 Larva still in Seeds.	2 Larvæ still in Seeds.	0 Larvæ still in Seeds.	2 Larvæ still in Seeds.	1 Larvæ still in Seeds.	1 Larva still in Seeds.	0 Larvæ still in Seeds.	0 Larvæ still in Seeds.	0 Larvæ still in Seeds.	0 Larvæ still in Seeds.	Large Numbers of live Larvæ in Seeds.

Table XLIII.

Emergence of Resting Pink Bollworms from 50 Double Seeds sown in Pots of Soil at Different Depths.

DATE.	POTS 1 TO 6 SOWN, AND WATERED ONCE ONLY ON MAY 1st 1913. DAILY EMERGENCE OF LARVÆ.						POTS 7 TO 12 SOWN AND WATERED 1st MAY AND WATERED AGAIN WHEN NECESSARY TO KEEP SOIL *ALWAYS WET*. DAILY EMERGENCE OF LARVÆ.						CONTROL SEEDS KEPT DRY.
	POT 1 1 CM.	POT 2 2 CM.	POT 3 3 CM.	POT 4 4 CM.	POT 5 6 CM.	POT 6 8 CM.	POT 7 1 CM.	POT 8 2 CM.	POT 9 3 CM.	POT 10 4 CM.	POT 11 6 CM.	POT 12 8 CM.	
3 May.....		1											
4 —		2											
5 —	1	1											
6 —	1	1					2	1	1				
7 —	3					2	2	2	1	2			
8 —			1	1	1	1	3	2		1			
9 —													
10 —	2	4			1	1	2	3	3	5	2	3	
11 —	5	3	5	11	4	6	1			1		1	
12 —	2		11	2				2			4	2	
13 —			1										
14 —			2						3			1	
15 —									3	1		3	
16 —													

July 6th Seeds examined.	15 live Pink Bollworms in seeds in Pots 1 to 6.							1 live Pink Bollworm in seeds in Pots 7 to 12.							Seed full of living Pink Boll-worms.
17 —				3					1		1		1		
18 —		1						1							
19 —												2	1		
20 —											1				
21 —									1	1	1				
22 —															
23 —															
24 —												1			
25 —		1									1				
26 —															
27 —										1		1			
28 —								1							
29 —								1							
30 —															
31 —															
1 June.....															
2 —															
3 —															
4 —															
5 —			1												

The seed in boxes Nos. 7 to 12 was covered with the same depth of soil as the other six and watered at the same time, but in this case subsequent waterings were given on April 29th and again on May 11th in order to keep the soil always in a wet condition. Table XLII shows the results obtained from this series of boxes.

It will be seen that a thorough wetting of the soil *at this date* had a very great effect on the pink bollworms causing them to leave the seeds and make their way to the surface, where, if left undisturbed, they spun cocoons and changed to the pupa stage and subsequently gave rise to the adult or moth state in May.

From the dry seeds kept as a control there was no movement of larvæ during the same period.

It is quite evident also, that the larvæ can easily find their way to the surface through 3 or 4 centimetres of compact wet soil up to as much as 8 centimetres. There is a slight difference in the number of larvæ emerging through the different depths of soil, but this is due more probably to variation in the number of live pink bollworms in the seed used than to the depth at which the latter was planted. It is possible, however, that some larvæ may not find their way to the surface through lack of strength to do so or from getting lost. What is the mortality, if any, from these causes, we do not know at present. There seems on the whole a tendency for the larvæ from the deeply sown seeds to arrive at the surface later than those from the shallow sown, a result only to be expected, but even this does not hold good in all cases.

A very important point shown by this experiment is that in spite of the repeated watering of the soil and a constant state of wetness, some larvæ remained in the seeds. It will be observed, if Table XLII be looked at, that the proportion of larvæ remaining in the seeds where the soil was watered once only is much higher than when three waterings were given. In the case of a similar trial carried out in the garden, the seed being sown on April 8th 1913, a few pink bollworms were found on April 30th, the soil was still quite damp at the time. Trials made more recently have again demonstrated that larvæ may remain in the seeds in

spite of repeated watering, this being due, it seems, to low temperature and also apparently to differing individual characteristics in the larvæ.

The finding of empty pupa cases in some of the seeds indicates that some larvæ may pupate *in situ*, but the successful escape of the moth will be somewhat doubtful as shown by Table XLIV (page 186) which gives the emergence of moths from pupæ buried at different depths. As regards this question a great deal will depend on the condition of the soil at the time of the moth's emergence from the pupa. One point in its favour under field conditions is that the soil around the stems of cotton plants tends to be loose and friable owing to its having been broken up by the germination and subsequent pushing through of the young plants.

Table XLIII gives the results of an exactly similar experiment to that recorded in Table XLII only large flower pots were used instead of boxes and the double seeds were sown on May 1st instead of April 16th.

The results in both cases are similar. One rather striking point is again manifest, namely that in those pots in which the soil was kept wet by repeated waterings, only one live bollworm remained in the seeds; but in the pots watered once only and then allowed to dry out, 15 larvæ were found and one pupa in a cocoon amongst the double seeds.

In the seed kept dry as a control no pink bollworms emerged.

Table XLV gives the result of a trial made in the laboratory garden of sowing infested « double seeds » and 8 to 10 sound cotton seeds under field conditions. The sown seed was covered over with a wire cage. The trial was not very successful owing partly to the failure of the seeds to germinate, as well as the damping off of the young seedlings — the result of shading by the cages — and furthermore, to the fact that ants showed a great partiality for the cages and the soil about the caged plants, which gave rise to the belief that they may have destroyed many of the pink bollworms and pupæ, since including moths only very few were recovered. However, the trial served to show that under field conditions (except for shade afforded by the covering cages) pink bollworms may leave the seeds, make their way to the surface, pupate, and give rise to the moth stage successfully.

Table XLIV.

The Ability of the Moth to Emerge through Varying Depths of Soil.

A. Soil Watered so as to keep it always wet.

DATES ON WHICH EXAMINED.	POT N° 1. 8 JULY 1915. 25 PUPÆ BURIED AT 1 CM. BELOW THE SURFACE.	POT N° 2. 8 JULY 1915. 25 PUPÆ BURIED AT 2 CM. BELOW THE SURFACE.	POT N° 3. 8 JULY 1915. 25 PUPÆ BURIED AT 3 CM. BELOW THE SURFACE.	POT N° 4. 8 JULY 1915. 25 PUPÆ BURIED AT 4 CM. BELOW THE SURFACE.	POT N° 5. 8 JULY 1915. 25 PUPÆ BURIED AT 5 CM. BELOW THE SURFACE.
1915.					
13 July.....	No moths have emerged.	No moths have emerged.	No moths have emerged.	No moths have emerged.	No moths have emerged.
17 —	0 — —	0 — —	0 — —	0 — —	0 — —
26 —	0 — —	0 — —	0 — —	0 — —	0 — —
28 August..... Soil Examined.	9 moths had partially emerged from pupæ and then perished. The other 16 had failed to emerge at all — had apparently been cemented in.	4 moths had partially emerged from pupæ and then perished. The other 21 as in Pot N° 1.	10 moths had partially emerged from pupæ and then perished. The other 15 as in Pot N° 1.	8 moths had partially emerged from pupæ and then perished. The other 17 as in Pot N° 1.	6 moths had partially emerged from pupæ and then perished. The other 19 as in Pot N° 1.

B. Soil watered once and then allowed to dry up and become hard.

DATES ON WHICH EXAMINED.	POT N° 1. 8 JULY 1915. 25 PUPÆ BURIED AT 1 CM. BELOW THE SURFACE.	POT N° 2. 8 JULY 1915. 25 PUPÆ BURIED AT 2 CM. BELOW THE SURFACE.	POT N° 3. 8 JULY 1915. 25 PUPÆ BURIED AT 3 CM. BELOW THE SURFACE.	POT N° 4. 8 JULY 1915. 25 PUPÆ BURIED AT 4 CM. BELOW THE SURFACE.	POT N° 5. 8 JULY 1915. 25 PUPÆ BURIED AT 5 CM. BELOW THE SURFACE.
1915.					
13 July.....	No moths have emerged.	No moths have emerged.	No moths have emerged.	No moths have emerged.	No moths have emerged.
17 —	0 — —	0 — —	0 — —	0 — —	0 — —
26 —	0 — —	0 — —	0 — —	0 — —	0 — —

28 August..... Soil Examined.	5 moths had partially emerged from pupæ and then perished. 20 pupæ dead, moths had been unable to split pupa case—had been cemented in by the hard soil apparently.	4 moths had partially emerged from pupæ. Rest of pupæ as in N° 1.	6 moths had partially emerged from pupæ. Rest of pupæ as in N° 1.	8 moths had partially emerged from pupæ and had then perished. Rest of pupæ as in N° 1.	4 moths had partially emerged from pupæ. Rest of pupæ as in N° 1.

C. Soil not watered. Kept dry and in a fine state.

DATES ON WHICH EXAMINED.	POT N° 1. 8 JULY 1915. 25 PUPÆ BURIED AT 1 CM. BELOW THE SURFACE.	POT N° 2. 8 JULY 1915. 25 PUPÆ BURIED AT 2 CM. BELOW THE SURFACE.	POT N° 3. 8 JULY 1915. 25 PUPÆ BURIED AT 3 CM BELOW THE SURFACE.	POT N° 4. 8 JULY 1915. 25 PUPÆ BURIED AT 4 CM. BELOW THE SURFACE.	POT N° 5. 8 JULY 1915. 25 PUPÆ BURIED AT 5 CM. BELOW THE SURFACE.
1915.					
13 July.....	2 moths have emerged.	9 moths have emerged, 1 slightly crippled.	9 moths have emerged, 1 crippled.	0 moths.	1 crippled moth, can't fly.
17 —	16 moths have emerged 1 crippled and can't fly.	8 moths have emerged, 1 crippled.	6 moths have emerged, 2 crippled and can't fly.	0 —	1 slightly crippled.
26 —	0 moths.	0 moths.	0 moths.	0 —	0 —
29 August.....	20 empty pupa cases.	22 empty pupa cases.	21 empty pupa cases.	21 empty pupa cases.	20 empty pupa cases.
Soil examined.	2 dead —	3 pupæ dead.	4 dead pupæ.	4 dead pupæ.	5 dead pupæ.
	3 moths had partially emerged from pupæ but failed to escape through the soil.	3 moths emerged but failed to escape from soil.	6 moths emerged from pupæ but failed to escape from soil.	21 moths emerged from pupæ but failed to escape through the soil.	18 moths emerged from pupæ but failed to escape through the soil.

Soil used in pots was a sandy soil.

Table XLV.

EMERGENCE OF RESTING PINK BOLLWORMS FROM DOUBLE SEEDS SOWN IN GARDEN APRIL 1913, AND COVERED WITH WIRE GAUZE CAGES.

EXAMINED.	CAGE 1.	CAGE 2.	CAGE 3.	CAGE 4.	CAGE 5.	CAGE 6.	CAGE 7.	CAGE 8.	CAGE 9.	CAGE 10.	CAGE 11.	CAGE 12.	CAGE 13.	CAGE 14.	CAGE 15.	CAGE 16.	CAGE 17.
1913.																	
May 14.....	—	M	M	M	2 L	0	—	—	—	—	—	—	—	—	—	—	—
— 22.....	0	0	0	M	0	0	L	0	0	—	—	—	—	—	—	—	—
— 25.....	—	—	—	—	—	—	—	—	—	0	0	0	0	0	0	0	0
— 26.....	0	0	0	0	0	0	0	0	0	0	0	0	0	M	0	M	2 P

L = Larva (Pink Bollworm) found in cage.
M = Moth of Pink Bollworm — —
P = Pupa — — — —
— = Cage not examined.
0 = Examined but nothing found.

From all the foregoing observations we may conclude that provided the temperature is sufficiently high, such as appears to be the case in April, the wetting of the soil has a great influence on the larvæ in the seed, causing them to abandon the resting or quiescent larval stage, make their way to the surface, pupate and subsequently transform to moths.

The higher the temperature is at the time of watering the more rapid and complete is likely to be the emergence of the resting larvæ. This is shown by the following record :—

In a large box a quantity of «double seeds» infested with pink bollworm had been stored in the hope of protecting the larvæ from destruction by the predaceous mite *Pediculoides ventricosus*. Examined on June 30th, 14 pink bollworms were found on the surface, but all had been killed by mites. In order to make some use of any remaining larvæ before

they succumbed *in situ* to the attacks of this mite, it was decided to water the box to see the result, which was as follows :—

July 2nd	9 larvæ have come up to the surface.
— 3rd	40 — — 5 had already spun cocoons.
— 5th	113 larvæ up to day, 25 of these had already spun cocoons.
— 6th	32 larvæ have emerged since yesterday.
— 7th	14 — — — and 1 pupa found.
— 8th	8 larvæ have emerged since yesterday.
— 9th	2 — — — and 1 pupa found.
— 10th, — 11th, — 12th, — 13th	No larvæ found.
— 15th	1 pupa found and 2 moths (evidently larvæ had pupated on surface and been overlooked).
— 19th	4 moths found.
— 21st	1 moth found. Soil watered again.
— 24th	No larvæ or moths found.
— 26th	— —
— 27th	Contents of box, including soil and seeds, carefully examined for live pink bollworms, but none were found, emergence of the resting larvæ having been complete.

In order to obtain more definite information on the behaviour of the resting pink bollworm in infested cotton seed when sown early — that is, in February and March — the experiments in pots were repeated this year (1915) in March. Two series, each of twelve large flower pots, were sown with « double seeds » on March 8th and watered the same day. One series was watered again at 30 days intervals, and in the other lot waterings were given when necessary to keep the soil *always* wet. Two pots in each series were kept dry as controls. The pots were kept in the Insectary, a wire-gauze structure in the laboratory garden with the roof covered with rush matting to protect the interior from direct sunshine.

Unfortunately the results given by these pots were very disappointing owing to the fact that the majority of the larvæ died *in situ* in the seeds in the pots which had been watered. This mortality was probably due to disease. However, it is noteworthy that no pink bollworms had left the seeds and made their way to the surface by the middle of April, and up

to this date it is known that many live larvæ were present in the seed. After April 15th a few larvæ came to the surface.

On June 16th the seeds were examined, and in the case of the pots in which the soil had been kept wet all the time no larvæ were found in the seeds, whereas when sown about 48 per cent contained living pink bollworms. In the dry pots, however, 50 per cent of the seed still contained living larvæ, so in this case it appears that moisture had rendered the larvæ very subject to the attack of disease, since we are quite certain that the larvæ could not have come to the surface and escaped from the pots owing to the manner in which the tops were covered.

In the second series of pots watered at 30 days intervals no larvæ came to the surface and when examined on June 16th., in 160 double seeds 6 live larvæ and 5 live pupæ were found, a total of 11 or 6.8 per cent only, but when sown 48 per cent of the seeds had contained live larvæ. On the other had in the control pots, kept dry, in 40 double seeds 20 live pink bollworms were found.

In the watered pots of this series several empty pupa cases were found in the seeds, but the moths had failed to reach the surface.

An experiment in which 10 infested «double seeds» and 10 healthy seeds were sown and watered on March 8th 1915 in 31 «holes» under field conditions in the laboratory garden, except that the seed was caged over, also failed to give results, as we were unable to trace any larvæ which may have left the seeds and came to the surface. On March 29th, that is, after the seed had been watered once only, an examination was made of 107 double seeds recovered from 20 out of the 31 holes sown. These seeds contained only 15 live larvæ, or 14 per cent. Originally the double seeds sown contained 48 per cent live larvæ. The difference may have been due to mortality from disease, but on the other hand larvæ may have left the seeds, reached the surface and there have been destroyed by ants which unfortunately became numerous about the cages. It is quite conceivable that there might have been a movement of larvæ from the double seeds sown on the ridge in the garden and not from the pots in the insectary, because in the former case the ridges would be well heated

up by the sun — already powerful in March — during many hours of the day, and in the latter case the pots were completely shaded all day from the sun.

Again, in this experiment it is important to note that whether or not some larvæ did leave the seeds others did not do so in spite of moist surroundings.

On April 18th 1915 a further quantity of double seed was sown on the ridge in the laboratory garden and heavily watered the same day. The seed was not covered with cages in this experiment. From April 23rd to April 29th numbers of larvæ left the seeds and appeared on the surface, even during the hottest part of the day when the surface of the soil was so hot that the larvæ were killed. But even in this case an examination of 167 double seeds dug up on May 3rd showed that 20 live pink bollworms had not yet abandoned the seeds, although no doubt many if not all of these would have done so after the second watering. When sown, about 48 per cent of the seeds contained live larvæ.

Simultaneously with the out-of-doors experiments, observations to ascertain the effect of temperature and moisture on the behaviour of the resting pink bollworm were made in the laboratory. The results obtained from these replace to a large extent those we failed to get from the experiments in the pots and in the garden.

In the laboratory two lots of larvæ were used :

Lot 1. — Resting larvæ were removed from double seeds.

Lot 2. — The larvæ were left undisturbed in the double seeds.

Lot 1 was divided into four series as follows :—

Series A^1 *to* A^{10}. — Larvæ re-made cocoon in *dry* cotton fibre placed in glass stoppered jars.

Series B^1 *to* B^{10}. — Larvæ re-made cocoons in cotton fibre placed in glass stoppered jars *half filled with wet sand.*

Series A and B kept in incubator at a constant temperature of 33.5° C.

Controls. — *Series* a^1 *to* a^{10}. — Conditions as for series A except that

Table XLVI.

The Influence of Temperature and Humidity

on the Behaviour of Resting Pink Bollworms when Removed from Cotton Seeds.

Reference Number of Larva.	Experiment commenced March 3rd.	Examined :— March 10th.	March 14th.	March 22nd.	March 29th.	April 5th.	April 12th.	April 18th.	April 26th.	May 3rd.	May 18th.	May 25th.	June 3rd.	Conditions of Experiment.
A. 1	x	x	x	x	x	x	x	x	P	M	,,	,,	,,	Bollworms subjected to raised temperature only.
2	x	x	x	x	x	x	x	x	x	P	M	,,	M	10 Resting larvæ removed from cotton seeds and placed in glass-stoppered glass tubes in which was placed some dry cotton. In this the larvæ spun cocoons.
3	x	x	x	x	x	x	x	x	x	x	x	P	M	
4	x	x	x	x	x	x	x	x	x	x	x	P	,,	
5	x	x	x	x	x	x	x	x	P	P	M	,,	,,	
6	x	x	x	x	x	x	x	x	P	M	,,	,,	,,	
7	x	x	x	x	x	x	x	x	P	P	M	,,	,,	Tubes kept in Incubator at 33.5° C.
8	x	x	x	x	x	x	x	x	x	P	M	,,	,,	
9	x	x	x	x	x	x	x	x	x	x	x	P	M	N. B.—A^1 to A^{10} were under *Hot* and *Dry* conditions.
10	x	x	x	x	x	x	x	x	x	P	M	,,	,,	
B. 1	x	x	x	P	M	,,	,,	,,	,,	,,	,,	,,	,,	Bollworms subjected to raised temperature and moisture.
2	x	x	P	M	,,	,,	,,	,,	,,	,,	,,	,,	,,	
3	x	x	x	x	P	M	,,	,,	,,	,,	,,	,,	,,	
4	x	x	x	x	x	,,	M	,,	,,	,,	,,	,,	,,	10 Resting larvæ treated as above but *wet sand* was placed at the bottom of the glass tubes.
5	x	x	x	x	P	M	,,	,,	,,	,,	,,	,,	,,	
6	x	x	x	P	M	,,	,,	,,	,,	,,	,,	,,	,,	Incubator 33.5° C.
7	x	x	x	P	M	,,	,,	,,	,,	,,	,,	,,	,,	
8	x	x	x	x	P	M	,,	,,	,,	,,	,,	,,	,,	N.B.—B^1 to B^{10} were under *Hot* and *Moist* conditions.
9	x	x	x	P	M	,,	,,	,,	,,	,,	,,	,,	,,	
10	x	x	x	x	P	M	,,	,,	,,	,,	,,	,,	,,	

Controls kept at Air Temperature of Laboratory.

a. 1	x	x	x	x	x	x	x	P	P	M	"	"	"	
2	x	x	x	x	x	x	x	x	x	x	x	x	x	
3	x	x	x	x	x	x	x	x	x	x	x	x	x	
4	x	x	x	x	x	x	x	x	x	x	x	P	M	10 Resting larvæ treated exactly as A^1 to A^{10} except that they were kept at the *Air Temperature* of the laboratory.
5	x	x	x	x	x	x	x	x	x	x	x	x	dead	
6	x	x	x	x	x	x	x	x	x	x	P	P	M	
7	x	x	x	x	x	x	x	x	x	x	x	x	x	
8	x	x	x	x	x	x	x	x	x	x	x	x	x	
9	x	x	x	x	x	x	x	x	x	x	x	x	x	
10	x	x	x	x	x	x	x	x	x	P	M	"	"	
b. 1	x	x	x	x	x	x	x	P	P	M	"	"	"	
2	x	x	x	x	x	x	x	x	P	P	M	"	"	
3	x	x	x	x	x	dead	"	"	"	"	"	"	"	
4	x	x	x	x	x	x	x	P	M	"	"	"	"	10 Resting larvæ treated exactly as B^1 to B^{10} except that they were kept at the *Air Temperature* of the laboratory.
5	x	x	x	x	x	x	x	x	x	P	M	"	"	
6	x	x	x	x	x	x	x	x	P	P	M	"	"	
7	x	x	x	x	x	x	x	x	P	P	M	"	"	
8	x	x	x	x	x	x	x	x	x	P	M	"	"	
9	x	x	x	x	x	x	x	P	P	M	"	"	"	
10	x	x	x	x	P	M	"	"	"	"	"	"	"	

x = Pink Bollworm in Larva Stage.

P = Pink Bollworm has changed to pupa.

M = Moth has emerged from pupa.

Table XLVII.

The Influence of Temperature and Humidity on the Behaviour of Resting Pink Bollworms in Cotton Seed.

Reference number of larva.	Experiment commenced March 3rd.	Examined :— March 10th.	March 14th.	March 22nd.	March 29th.	April 5th.	April 12th.	Change of conditions.	April 18th.	April 26th.	May 3rd.	May 18th.	May 25th.	Conditions of Experiment.
C. 1	x	x	x	x	x	x	x	Seed kept on Dry cotton wool over water. Nos 1 to 5.	x	x	P	M	No Records made after May 25.	Bollworms subjected to *raised temperature* only. 18 Resting Larvæ in double seeds kept in glass tubes. Seeds placed on *dry* cotton. Kept in Incubator at 33.5° C.
2	x	x	x	x	x	x	x		x	x	x	x		
3	x	x	x	x	x	x	x		x	x	x	P		
4	x	x	x	x	x	x	x		x	*	P	M		
5	x	x	x	x	x	x	x		x	x	x	P		
6	x	x	x	x	x	x	x	Seed put in wet sand. Nos 6. 7. 8.	x	P	P	M		
7	x	x	x	x	x	x	x		*	P	M	"		
8	x	x	x	x	x	x	x		x	*	*	dead		
9	x	x	x	x	x	*	P		M	"	"	"		
10	x	x	x	x	x	x	x		x	x	x	x		
11	x	x	x	x	x	P	M		"	"	"	"		
12	x	x	x	x	x	P	M		"	"	"	"		
13	x	x	x	x	x	x	x	No change made.	x	P	M	"		
14	x	x	x	P	M	"	"		"	"	"	"		
15	x	x	x	x	x	x	x		x	P	M	"		
16	x	x	x	x	x	x	x		x	x	x	x		
17	x	x	x	x	x	x	x		x	*	P	M		
18	x	x	x	x	x	x	x		x	x	x	x		
D. 1	x	x	*	*	P	M	"	No change made in conditions of Experiment, April 12.	"	"	"	"	"	Bollworms subjected to *raised temperature and moist atmosphere*. 20 Resting Larvæ in double seed sown in *wet* sand in glass tubes. Kept in Incubator at 33.5° C.
2	x	x	*	*	P	M	"		"	"	"	"	"	
3	x	x	*	*	P	dead	"		"	"	"	"	"	
4	x	x	*	*	*	*	*		P	M	"	"	"	
5	x	x	*	*	*	*	*		*	*	*	P	M	
6	x	x	*	*	P	M	"		"	"	"	"	"	
7	x	x	*	*	*	*	P		M	"	"	"	"	
8	x	*	dead	"	"	"	"		"	"	"	"	"	
9	x	x	*	P	M	"	"		"	"	"	"	"	
10	x	x	*	P	M	"	"		"	"	"	"	"	
11	x	x	*	P	M	"	"		"	"	"	"	"	
12	x	x	x	P	d	dead	"		"	"	"	"	"	
13	x	x	x	*	*	*	P		M	"	"	"	"	
14	x	*	P	P	dead	"	"		"	"	"	"	"	
15	x	x	*	*	P	M	"		"	"	"	"	"	

16	x	x	*	P	M	„	„		„	„	„	„	„	
17	x	x	x	P	M	„	„		„	„	„	„	„	
18	x	x	*	*	P	M	„	do.	„	„	„	„	„	do.
19	x	x	*	*	P	M	„		„	„	„	„	„	
20	x	x	x	*	P	M	„		„	„	„	„	„	

Controls kept at Air Temperature in Laboratory.

c. 1	x	x	x	x	x	x	x		x	x	x	x	x	
2	x	x	x	x	x	x	x		x	x	x	x	x	
3	x	x	x	x	x	x	x		x	x	x	x	x	
4	x	x	x	x	x	x	x		x	x	x	x	x	
5	x	x	x	x	x	x	x		x	x	x	x	x	
6	x	x	x	x	x	x	x		x	x	x	x	x	
7	x	x	x	x	x	x	x	No change made in	x	x	x	x	x	Conditions as for C[1] to C[18]
8	x	x	x	x	x	x	x	conditions of Experi-	x	x	x	x	x	But kept at *Air Temperature* of the
9	x	x	x	x	x	x	x	ment, April 12.	x	x	x	x	x	laboratory.
10	x	x	x	x	x	x	x		x	x	x	x	x	
11	x	x	x	x	x	x	x		x	x	x	x	x	
12	x	x	x	x	x	x	x		x	x	x	x	x	
13	x	x	x	x	x	x	x		x	x	x	x	x	
14	x	x	x	x	x	x	x		x	x	x	x	x	
15	x	x	x	x	x	x	x		x	x	x	x	x	
16	x	x	x	x	x	x	x		x	x	x	x	x	
d. 1	x	x	x	x	x	P	M		„	„	„	„	„	
2	x	x	x	*	*	*	P		P	M	„	„	„	
3	x	x	x	x	x	x	x		x	x	x	M	„	
4	x	x	x	x	x	x	x		x	x	x	M	„	
5	x	x	x	x	x	x	x		x	x	x	P	„	
6	x	x	x	x	x	x	x		*	*	P	dead	„	
7	x	x	x	x	x	x	x		*	*	*	*	„	Conditions as for D[1] to D[20]
8	x	x	x	x	x	*	*		*	*	P	dead	„	But kept at *Air Temperature* of the
9	x	x	x	x	x	x	x		x	x	x	x	„	laboratory.
10	x	x	x	x	x	x	x		P	P	P	M	„	
11	x	x	x	x	x	x	x		x	x	P	M	„	
12	x	x	x	x	x	x	x		x	x	x	P	M	
13	x	x	x	x	x	x	x	Injured.	„	„	„	„	„	
14	x	x	x	*	*	*	*		*	*	*	P	M	
15	x	x	x	x	x	x	x		x	dead	„	„	„	

x = Resting Pink Bollworm in *Larvæ stage* in a double seed.
* = The larva has now left seed and spun cocoon amongst cotton in tube.
P = The larva has now changed to pupa stage.
M = The moth has emerged from pupa.

the jars were kept at the air temperature of the laboratory, about 70°-75° during March and April, 75°-80° during May.

Series b^1 *to* b^{10}. — Conditions as for Series B except that jars were kept at the air temperature of laboratory.

Lot 2 :

Series C^1 *to* C^{18}. — Larvæ in double seeds resting in *dry* cotton wool.

Series D^1 *to* D^{20}. — Larvæ in double seeds *sown in wet sand.*

Both Series C and D kept in incubator at constant temperature of 33.5° C.

Controls. *Series* c^1 *to* c^{16} and d^1 *to* d^{15} were treated exactly the same except that they were kept at the air temperature of the laboratory.

Tables XLVI and XLVII show the results of these experiments. In the A and B Series, the larvæ subjected to a high and damp temperature pupated much sooner than those under hot but dry conditions. The latter (A) pupated sooner than the control series a^1 to a^{10} which were kept at the air temperature of the laboratory. As regards the controls, a considerable difference is apparent in the earlier and more general change to the chrysalis stage in the case of b^1 to b^{10}, which were under moist conditions, than in a^1 to a^{10} kept dry.

The larvæ in the double seeds behaved as they were expected to. In Series D^1 to D^{20} the larvæ left the seeds and pupated. In the Series C^1 to C^{18} kept dry, there was no movement from the seeds — except in one case — for a long time after the larvæ subjected to moisture had commenced to leave the seeds.

The controls are even more interesting. In the dry Series c^1 to c^{16} no larvæ left the seeds during the whole period they were under observation. In the wet Series d^1 to d^{15} there was very little activity during March, but with an increase of temperature from the middle of April to the beginning of May the larvæ commenced to abandon the seeds and pupate.

These experiments confirm the results of those carried out before and which showed us that the resting pink bollworm is influenced to a marked

degree by an abundance of moisture plus a high temperature, the tendency being, under such conditions, for it to abandon the resting state, transform to the pupa and subsequently to the moth stage. At the same time, however, it is equally evident that a superabundance of moisture is not essential before this change takes place, since it eventually occurs under the normal humidity conditions of the atmosphere. Super-abundant moisture plus the necessary temperature merely hastens the change to the pupa stage, and as regards this there is a tendency to individual variation on the part of resting pink bollworms.

We are now in a better condition to discuss the question of the danger of the pink bollworm in the tagawi seed acting as a source of infection of the new crop.

In the case of seed sown in February and early March the probability seems that the first watering will result in little or no movement towards the surface owing to the temperature not being sufficiently high at this time of the year — at any rate in Lower Egypt. The second watering in the Middle Delta will take place about, say the middle of April, after which there is likely to be a big movement of resting larvæ towards the surface where those fortunate to escape destruction from one cause or another may find favourable situations in which to pupate; these larvæ will give rise to moths — say in the first week of May. But the cotton will not be sufficiently advanced to support the offspring of these moths for at least another month or six weeks and thus they must live for this period before they can oviposit with any chance of success. Now how many moths will live or escape destruction during this period? It is impossible to say, but one would think the number would be in all probability small, but nevertheless of importance.

As regards this question it must be pointed out that conditions vary according to locality. For instance, sowing in Upper Egypt takes place during the first week in February; but in the Northern Delta the crop may not be sown until the end of March or beginning of April. It is probable, however, that the gap between the time the moths (originating from resting pink bollworms sown in the seed) may be expected to

emerge and the time when the cotton bears «squares» of a size to support their offspring will be much about the same for any part of the country.

There is one important point which must not be lost sight of, viz., that we know that some larvæ may not leave the seeds after the first watering and perhaps the second also. But a watering which takes place, say from the middle to the end of May is likely to bring the majority to the surface. It is these late arrivals that are really dangerous, and the later the larvæ leave the seed the more dangerous they are, for those which succeed in reaching the moth stage are likely to find the cotton sufficiently advanced for oviposition to take place, or at any rate a short time after their appearance.

So far we have not spoken of the dangers to which the larvæ sown in the tagawi seed will be exposed in the ground and when they reach the surface. These dangers, however, are of the greatest importance since they reduce the risk of the larvæ giving rise to re-infection of the new crop.

In the first place the moist condition of the soil when the temperature is low is likely to induce disease amongst the larvæ or at all events make them more subject to it. As an instance of this we have the case of the double seeds sown in pots in March of this year. In the pots kept wet the larvæ died, but in the controls in which the soil was dry the larvæ did not die, or only very few of them.

Ants, when they occur, may attack the larvæ in the seeds.

So much for the dangers which beset the pink bollworm when it is in the soil. Now, what will happen to it when it reaches the surface?

Observations made on larvæ sown in double seeds in the laboratory garden gave one the impression that they were decidedly ill at ease on reaching the surface. They crawled about very fast in a haphazard manner across the ridges or along the furrow between two ridges until they reached the tin water trough surrounding the plot. They made no attempt to spin cocoons under lumps of earth on or between the ridges, probably it was too hot there, but some did pupate under some flower pots

standing between two of the ridges, these affording apparently sufficient protection from the sun.

The larvæ frequently fell into the cracks in the soil — the result of watering — but they did not remain there, but made their way to the surface again and continued their travels. Whether larvæ ever do pupate in the cracks in the soil in Egypt at this time and to what extent we do not know for certain, but Maxwell Lefroy [32] says they may pupate in these situations in India on heavy soils which crack deeply and freely. One would be led to think they would do so here also, for it is certain that the larvæ must more often than not tumble into these cracks when crawling about on the surface.

In this case many larvæ died from heat, the ridges being dry and the sun hot, and no doubt a great many do so under ordinary field conditions when they come to the surface during the daytime during April and May.

The later in the year the pink bollworms emerge from the seed and reach the surface the greater will be the risk they run of being killed by sun heat. This is most fortunate because, as has already been pointed out, it is these late larvæ which, if they succeed in giving rise to moths, are the most dangerous, since the females will find or will shortly find the cotton in such an advanced state as to permit of their lying eggs with success — that is to say, the young larvæ which hatch from the eggs will find squares of sufficient size to furnish them with suitable food.

Under field conditions, no doubt some of the larvæ would reach the borders of the field where so frequently there is a grassy bank of a small canal, which even if in some cases it is free from grass often contains numerous cracks and crevices where the larva might find suitable surroundings to pupate. In the north of the Delta one sees large clods of earth bound together by grass roots in some cotton fields. Larvæ might pupate under such protection which, however, will be in all probability but temporary only, as the lumps get broken down when the field is cultivated between the waterings.

During their travels on the surface the bollworms, in addition to the risk of being killed by the heat of the sun are also exposed to the attacks of birds such as crows and sparrows, both of which have been observed to eat the larvæ; and there is also the crested lark — an insect feeder and a fairly common bird about the cotton fields in Lower Egypt *early* in the season. Larvæ which emerged during the night or in the early morning or late afternoon would stand the best chance of reaching a place of safety in which to pupate, but even these run the risk of attack by nocturnal predaceous beetles, spiders, and perhaps toads and frogs as well.

Those larvæ which may have pupated in cracks in the soil or under clods of earth if not killed by sun heat, which they certainly would be unless situated in a deep crack or under a large mass of soil and grass roots, have to pass through the dangers of cultivation by fassing or hoeing following the first, second or third waterings when the soil has dried sufficiently. This operation would tend to bury the pupæ so that when the moths emerged they might not be able to reach the surface.

From these remarks it will be understood that the mortality amongst the resting larvæ coming from the tagawi seed after it has been sown is likely to be very high, but at the same time it is probable that a few of them may find situations on the borders of the field in which they will be able to pass through the pupal stage in safety and in due course emerge as moths. The danger of the latter laying eggs on the new crop will depend on the date of their emergence and whether or not the cotton bears squares of sufficient size to support the larvæ. Those moths emerging very early may or may not be able to live until the cotton is sufficiently advanced for oviposition, but on the other hand we do not really know if the moths can live for a period of several weeks *without* lying their eggs somewhere, once they have developed; and in April and May the eggs develop quite rapidly to full size in the ovaries.

At this period the dangers of the pink bollworm are not over when it has once reached the adult stage, for the moths are always liable to destruction by bats and spiders and thus the number of those originating from the tagawi seed may be still further reduced.

With regard to those bollworms which pupate *in situ* in the seed; the chance of the moth being able to reach the surface will be, as has already been pointed out (page 186), very problematical.

In conclusion, it may be said that the probability is, that sowing seed infested with live pink bollworms does undoubtedly constitute a danger to the new crop in so much as there is a good chance of its being infected from this source, but at present we are not really in possession of sufficient date on the subject to say just what the extent and importance of this danger is in comparison with other sources of infection. In the opinion of the writer the danger to be apprehended from this origin is for the reasons mentioned above less than generally thought, and certainly infinitely less than the danger of allowing cotton sticks of the previous crop with the bolls adhering to them to the remain in the fields and villages until late in the summer of the new crop*.

One point which tends to support this opinion is the small extent to which the cotton is attacked in June and July (see Table XXXIII). If many moths originated from the tagawi seed one would expect the fact to be manifested by a much heavier attack at this period than appears actually to be the case. On the other hand we have the fact of the rapid spread of the pest in Egypt which tends to incriminate the seed as perhaps materially helping in this dissemination, although as a matter of fact it need not necessarily have been sown to affect this, but the infection may have arisen from stocks of seed remaining in the merchants' hands in various places. Furthermore it must not be forgotten that in a country like Egypt the natural spreading out of the pest from any one centre of infection by the winged insect or moth is likely to be fairly rapid.

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* Both the question of fallen bolls and the sowing of seed infested with resting pink bollworms may be of greater importance now that we know these larvæ may attack and subsist on the stems of the cotton plants. However, we require more detailed information on this habit than we possess at present, before its real significance as regards this question can be discussed at all fully.

Lastly, whilst there is a risk that the new crop may be infected by sowing infested tagawi seed, then it cannot be denied that it will be a much sounder and safer practice to sow seeds containing *no* living pink bollworm and this of course can only be done if the seed is first treated by fumigation or heat at the ginning factories, before it is distributed to the growers or the merchants who sell to the small cultivators. However, it is equally obvious of course that fumigation of the seed will be of little or no importance unless the destruction of all bolls left on the plants after the last picking is carried out completely by *all* cultivators, and in addition that the pest is also destroyed in *all stocks of cotton seed* which may remain in the country until May or later. This can likewise only be ensured by treatment in the ginnery.

OTHER SOURCES FROM WHICH THE NEW COTTON CROP MAY BECOME INFESTED WITH PINK BOLLWORM.

In addition to the pink bollworms in the bolls left on the cotton sticks, fallen bolls buried in the soil by ploughing, etc. and the sowing of infested tagawi seed giving rise to an attack on the new crop by this pest there are quite possibly also other important sources of infection which must not be overlooked.

I. Cotton seed. — In normal years the bulk of the cotton seed is exported from Egypt, but the shipment from Alexandria and its dispatch to this port from the interior is gradual and continues until well on into the summer. Moreover, a large quantity of seed remains in the country to be crushed for oil at various centres. All the seed from such crops as those of 1913 and 1914 will be infested with pink bollworm, and much of it very badly so. A very large number of the resting larvæ are likely to escape death by disease or the attacks of the predaceous mite *Pediculoides*

ventricosus and will give rise to moths. Thus any cotton seed remaining in store until May, June, or July, which is within reasonable distance of cotton fields must be regarded as a distinct danger, since it is a source from which cotton may easily become infested. The extent of this danger will depend of course on the amount of seed and how general its distribution is, the location of the seed and the date to which it remains in store. In some parts of the country where the cotton is forward, seed kept until April only may be a decided danger.

It must not be thought that if the seed is kept in sacks the danger will be averted owing to the inability of the moths to make their escape. This will not be so, because the resting pink bollworm when it leaves the seed eats or forces its way through the sack and pupates outside in a fold or crease in the sack, between two sacks, or between a sack and the floor or wall, etc., thus ensuring a clear way of escape for the moth when it emerges. The larva will behave in the same manner if it is in a heap of cotton seed, endeavouring to work its way to the surface before it pupates. Some larvæ, as we know, pupate *in situ* in the seeds and if these happen to be in a sack or deep in a heap of cotton seed the moths will of course be unable to escape and will perish.

Resting pink bollworms may emerge in small numbers from seed as early as March or April, but the big migration does not take place until the end of June or in July and August. At this period when they may emerge, say in hundreds or thousands, the larvæ are much exposed to the attacks of any ants whose nests may be in or about the stores and also to the mite *P. ventricosus*. However, as regards this mite, the writer is by no means certain that it breeds so actively in July and August owing to the prevailing high temperature combined with dryness. For instance, recently in the case of a sack of low grade cotton seed kept for observation in the laboratory, the seed was swarming with mites at the beginning of June; they left the sack and covered the table on which the sack was placed in countless numbers and any pink bollworm which happened to leave the seed at this time was immediately attacked and destroyed. At the end of June and beginning of July when the pink bollworms left the

seeds in hundreds the mites had practically disappeared and the larvæ pupated unmolested.

The danger of infection from cotton seed does not apply only to large bulks of this commodity collected at a comparatively few centres for crushing or export, but with equal and in fact greater degree to small lots left in the hands of provincial seed merchants, and the remainders of tagawi seed left over from sowing and put away in the store of an ezbeh, or to odd lots of refuse seed left about the yards of ginning factories, etc.

II. Low grade seed cotton kept by ginning factories for cleaning and trying the gins before ginning the new crop. — It is the practice of some ginners to keep a certain quantity of low-grade seed cotton from one season to the other for the purpose of cleaning and adjusting the gins before they commence on the ginning of the important first picking of the new crop. Whether or not this is a common practice we are not aware, but any seed cotton so kept will be a danger to the new crop if it is stored within reasonable distance of cotton fields. Low-grade seed cotton from the third and fourth pickings contains very large numbers of resting pink bollworms. This applies also to any unsold and unginned stocks of cotton in the hands of the growers, which have been held in the hope of obtaining a better price in the following year.

III. Ginning factories and seed stores as a possible source of infection. — One would expect to find resting pink bollworms spun up in cocoons in and about ginning factories and seed stores in cracks and crevices of the walls, floors etc., but so far we have not been able to confirm this. However, a much more extended and careful search than we have so far been able to make is necessary before any conclusion on this matter is reached. If in the future any danger from this source is proved, it could easily be avoided by making these buildings moth tight by wire screening open windows and ventilators, etc.; this will be much simpler than fumigation.

NATURAL CONTROL.

MORTALITY AMONGST THE PINK BOLLWORMS IN THE LARVAL STAGE.

Mortality in the field during summer months. — As far as our observations go at present the mortality amongst the larvæ in the field during the summer months, once they have gained the interior of a green boll, appears to be remarkably small, in fact it is exceptional to find a dead larva. In 1914, out of 3,369 larvæ found in unripe bolls from many localities during the summer and autumn months only 10 are recorded as «dead», that is, a percentage of 0.29. The cause of death in these cases was not ascertained.

Mortality amongst the resting larvæ in ginned cotton seed. — In the case of the resting larvæ in cotton seed the mortality is high. In January it will be found about 30 per cent, based on the examination of larvæ in «double seeds». In May, 50 per cent of the larvæ may be dead, and later in the year the mortality is believed to be very much higher still.

There are several causes which account for this mortality amongst the resting larvæ, the most important of them being — at all events during the autumn, winter and spring months — a disease the nature of which is unknown. There is also the protozoon disease known as *Microsporidium polyedricum*, first recorded as attacking the pink bollworm by Dr. L. H. Gough[33]. In addition, there is the predaceous mite *Pediculoides ventricosus* to whose attacks a great many larvæ may succumb during May and the following hot months.

The larvæ killed by disease will be found to be flattened, shrunken and dry or in many cases rather oily; in colour they are brownish or dark reddish. Pink bollworms which have been destroyed by the mites can be recognized by their pronounced yellow colour spotted with minute black spots, or the presence of the living or dead mites on their bodies.

«Double seeds» from 1913 crop examined between January 14th and February 9th 1914 gave the following results :—

Number of Double Seeds	5,447	
Number of Larvæ found	4,353	
Living Larvæ	2,763	or 63.4 %
Larvæ killed by mites	55	or 1.2 %
Larvæ dead and dried up, killed by disease	1,535	or 35.4 %
		100.—

A sample of 250 «Double Seeds» (1914 crop) examined in March and May 1915, gave the following results :—

	March 16th 1915.	May 19th 1915.
Number of Double Seeds	250	257
Number of Larvæ	215	219
Number of Live Larvæ	141 or 65.5 %	111 or 50.6 %
Number of Larvæ killed by mites	10 or 4.6 %	19 or 8.6 %
Number of Larvæ dead and dried up, killed by disease	64 or 29.9 %	89 or 40.8 %
	100.—	100.—

Mortality amongst the resting larvæ in the dead bolls. — Speaking generally, the mortality amongst the larvæ passing the resting stage in the dry bolls appears to be less than in ginned cotton seed, but at the same time it will be readily apparent that the death rate in this situation from natural causes will vary according to the conditions under which the bolls are placed. If, for instance, the bolls are exposed to sun, the mortality might reach 100 per cent by the month of June.

As in the case of the seed the death of the larvæ appears to be due chiefly to a disease and to a much less extent *Pediculoides ventricosus*.

Table XLVIII shows the number of dead larvæ found in dry bolls examined at different dates.

Table XLVIII.

Mortality amongst Resting Pink Bollworms in the Dry and Injured Bolls.

EXAMINED.	NUMBER OF BOLLS EXAMINED.	NUMBER OF LARVÆ FOUND.	NUMBER OF LIVE LARVÆ.	PER CENT OF TOTAL.	NUMBER OF DEAD LARVÆ.	PER CENT OF TOTAL.	CAUSE OF DEATH.			
							KILLED BY PEDICULOIDES.	PER CENT OF TOTAL DEAD.	DEATH DUE TO OTHER CAUSES.	PER CENT OF TOTAL DEAD.
December 28, 1913.	250	278	256	92	22	8	"	"	22	100
April 4, 1914.....	50	80	64	80	16	20	8	50	8	50
June 7, 1914.....	100	139	116	83.4	23	16.6	5	22	18	78
September 24, 1914.	75	26	5	19.2	21	80.8	"	"	21	100

The bolls examined were all from the same sample.

Other causes of mortality amongst the resting larvæ. — In addition to the two causes mentioned the death of larvæ is brought about by various Hymenoptera parasitic on the pink bollworm, but at present we have no means of determining the deaths from this cause, since once the adult parasite has emerged, little trace of it is left which can be easily detected.

MORTALITY IN THE PUPA, MOTH, AND EGG STAGES OF THE PINK BOLLWORM.

So far we have no information as to the degree of mortality which occurs in these stages of the pink bollworm's life-history the eggs are attacked and destroyed by small sucking bugs and perhaps other predaceous insects as well; not improbably the mortality in this stage is high.

No enemies which prey directly on the pupæ have been observed as yet. As regards the moths we also lack information : spiders are believed to account for the lives of some, and no doubt bats do so as well.

Amongst the numerous female moths of this species which have been dissected, certain individuals have been observed whose ovaries appeared to be in an abnormal condition, many of the ova having the appearance of having broken down or being in the process of breaking down. Possibly this is due to a disease (? *Microsporidium*), but if it is, we do not know what part it plays as regards the life of the adult; but judging by the internal appearance of these moths one would think that their laying capacity must be affected.

NATURAL ENEMIES.

As one would expect in the case of an insect so well protected during the greater part of its life, the pink bollworm is not apparently particularly subject to the attacks of natural enemies, especially those of a parasitic nature, either in Egypt or so far as we know at present in other countries where it occurs. This state of affairs is still less surprising in the case of Egypt than in others, since *G. gossypiella* has been introduced here quite recently and so it may quite well have happened that the pest has left behind many if not all the natural parasites to the attacks of which it may be subject in its country of origin — India. But no doubt further researches in any part of the world inhabited by this species will add to the list of the few parasites so far recorded. As regards Egypt, we do not know as yet if the parasites that prey upon the pink bollworm are in all cases indigenous insects which have adopted the new-comer as a new host, or whether they have been introduced into this country along with their host. In the case of one or two of the parasitic species observed here it seems that either of these two possibilities may actually be the case.

In addition to the two or three parasitic insects known to attack the pink bollworm in the field, there are a considerable number of other parasitic Hymenoptera — chiefly small to very small species — which

emerge from cotton bolls infested with *G. gossypiella*, *Earias insulana* and *Pyroderces simplex*. One also finds small beetles inhabiting the damaged bolls and these too may have parasites. Thus to establish the host relationships of the various Chalcids, etc., that can be reared from infested cotton bolls will be no easy matter and will certainly require a considerable time. Furthermore, to add to the difficulty, it is quite possible that we have several classes of parasites to deal with; namely, primary parasites — that is to say insects directly parasitic on one or both of the bollworms or other larvæ found in cotton bolls — and secondary or hyperparasites which are parasites of the primary parasites. The latter class are of course not beneficial at all since they naturally check and perhaps seriously interfere with the useful work of their hosts — the primary parasites — in destroying the bollworms, etc.

As regards the future value of the known parasites as a check on the undue increase of the pink bollworm we have already remarked that in the present state of our knowledge of these insects there is little that can be said of value on the subject. Before we are in a position to make forecasts it will be necessary to know far more about the complicated relationships that may exist between host and parasite. As an example of this we have the case of *Pimpla roborator* — a parasite of the pink bollworm, which as soon as it becomes over-numerous appears to automatically check its own increase by self-parasitism or what, practically speaking, amounts to assassination of its own kind.

Speaking generally, however, it seems fairly certain that the parasites have increased very considerably since *G. gossypiella* first gained a footing in Egypt, because previously these species were either altogether unknown — or unrecorded is perhaps a better term — in this country or else they were exceedingly rare; whereas at the present day they are common insects. Whether or not this increase will continue remains to be seen. As regards recent experience, some of the known parasitic insects seemed more numerous in 1914 and others less so than was the case in 1913. No doubt it will be asked why should not the parasites continue to make progress considering that their host, the pink bollworm, is still

numerous and likely to remain so for some little time to come. In reply I can only point out that as regards the parasites which may have been present in Egypt before the advent of the pink bollworm, there is always the possibility — one is perhaps justified in saying the probability — that they will suffer to a much greater extent from the attacks of their own or hyperparasites (supposing they possess any) or from some form of secondary parasitism such as occurs in the case of *Pimpla roborator*, owing to the very fact of their being abundant. This of course would tend to leave matters in favour of the pink bollworm which under such circumstances would undoubtedly increase again, since we have ample evidence to show us that it is a very dominant species. In any case it is almost certain or at all events highly improbable that the pink bollworm will ever be exterminated by the attacks of parasites and predaceous enemies. Likewise it is also extremely improbable that the pest will ever be held in *complete* subjection by this means. However, at the best, it is quite possible that in time the parasites will become sufficiently numerous to establish some sort of equilibrium between themselves and their host, or to at least afford material help in checking the increase of the pest beyond all bounds. In fact there can be no doubt that something of this sort has already taken place, for if it were not for the combined effect of parasitic and predaceous insect and mite enemies, disease and birds, the pest would have *destroyed* the cotton crop and not merely severely injured it. Thus it must not be thought that the work of the natural enemies is not of importance — it is and moreover, the fact is fully appreciated; but at the same time it will I think always be necessary for cotton growers to rely chiefly on preventive cultural methods for the effective control of the pest and so stop it to from annually causing serious harm.

As regards predaceous insects only very few species have so far been noted to feed on the pink bollworm which is open to attack by this class of natural enemy at two or three periods of its life only viz. — in the egg stage; the newly hatched larval stage, and again, when the full grown larva leaves the boll to pupate. At this latter stage it is only likely

to fall a victim to the strongest of predators, which are not particularly numerous.

Birds, owing to their scarcity during the greater part of the cotton season, are of little importance as checks on *Gelechia*. A disease, the nature of which is unknown to me, causes the larva to become at first limp and flabby and then to turn dark, shrivel and dry up until it becomes brittle and somewhat mummified — gives rise to a high mortality amongst the resting larvæ and is believed to be of considerable importance as a natural check.

PREDACEOUS INSECT AND MITE ENEMIES OF THE PINK BOLLWORM.

HEXAPODA OR INSECTS.

THE TRIPHLEPS (*TRIPHLEPS SP.*).

This small dark coloured bug, in its various instars, destroys the eggs of the pink bollworm by sucking out the contents and so prevents them hatching. It is not improbable also that they prey upon the minute newly hatched larva when it is wandering about in search of a boll, but this act has not so far been actually observed. Triphleps is a fairly common insect on cotton plants and no doubt causes considerable mortality amongst the eggs of the pink bollworm; this stage being one of, if not the most vulnerable periods in the life of the pest. The larva and nymph stages (Plate VI, Figs. 10-12) are particularly fond of inhabiting the buds and young leaves at the growing points of the stem and branches, also the bolls; and it is in these situations that the pink bollworm moth frequently lays her eggs.

The adult Triphleps (Plate VI, Fig. 10) is a small insect measuring only some 2 mm. in length by 1 mm. in breadth, coloured black and dark brown with the tips of the wings silvery in hue. The nymphs are

yellow heavily shaded with brown or blackish; the eyes are red. The larval stage is reddish to orange in colour, depending on the age of the insect; the eyes are ruby red.

The complete life history is not known, but it is believed that the female lays her eggs in the tissues of the small leaves of the growing points of cotton and other plants. Breeding continues throughout the summer: the winter is thought to be passed chiefly in the adult stage. The adults may often be found in cotton flowers and at the end of the season in the dry bolls which have been destroyed by the bollworm.

Triphleps also feeds on Aphides.

ANTS.

The common garden and house ant fiercely attacks the pink bollworm whenever it gets a chance, even mining the damaged bolls to get at the larvæ alive or dead. But in the cotton fields ants are rare so that their work cannot be considered of much account. It is probable, however, that they may destroy numbers of pink bollworms in bolls on cotton sticks lying in or about villages and buildings and especially pink bollworms emerging from stored cotton seed in June and July, and again in September and October when the unginned cotton or cotton seed lying in the stores or shoonas.

OTHER PREDACEOUS INSECTS WHICH MIGHT DESTROY THE PINK BOLLWORM.

Any of the following insects might prey upon the eggs and the newly hatched larvæ of the pink bollworm, although so far we have no definite records of their doing so :—

1. The larvæ of the Lace-wing (*Chrysopa vulgaris*, Sch.).

2. *Pæderus fuscipes*, Curtis. — a beetle.

3. *Microlestes lævipennis*, Luc. — a beetle.

4. *Laius venustus*, Er. — a beetle.

Any pink bollworms that may leave the bolls during the night in order to pupate might be snapped up during their travels on the ground in search of a suitable place in which to spin a cocoon, by such predatory beetles as *Calosoma rugosum*, de G.; *Scarites planus* v *bisquadripunctatus*, Klug.; and *Abacetus æneolus*, Chaud.; which are known to inhabit cotton fields.

ACARINA OR MITES.

THE PREDACEOUS PEDICULOIDES.

(*Pediculoides ventricosus*, Newport.)

This mite *, quite a common enemy of the resting pink bollworm in cotton seed and less so in the dead bolls, is a member of the order Acarina, which includes such well-known creatures as cheese mites, the so-called red-spiders, harvest mites or harvest bugs, etc. It was first described as a species in 1850 by Newport under the name of *Heteropus ventricosus*. Since 1850 this *Pediculoides* has received attention and been redescribed under other names by several authors. Braun [34] gives the following synonomy :—

Heteropus ventricosus, Newport., 1850; *Acarus tritici*, Lagrèze-Fossot., 1851; *Physogaster larvarum*, Lichtenstein., 1868; *Spærogyna ventricosa*, Laboulbène and Mégnin., 1885.

ROLE, ECONOMIC IMPORTANCE AND HOSTS OF THE MITE.

The normal role of *P. ventricosus* is a beneficial one, since it destroys other insects injurious to field and garden crops, trees, etc., feeding on these pests as an external parasite. Occasionally in its search for food it

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* For the account of this mite I have drawn largely on my previous papers on the subject.

attacks man, thereby changing its role and becoming noxious to him. In this case the bites of the active and non-gravid young female mites give rise to an irritating itching and erythema of the skin.

The insect hosts of this mite are numerous. It was discovered by Newport in 1849 in the nests of a bee (*Anthophora sp.*). Lichtenstein, who recorded the species under the name of *Physogaster larvarum*, was much troubled by it in his laboratory : the mites attacked and destroyed larvæ of *Hymenoptera, Buprestidæ, Cerambycidæ,* and some *Lepidoptera.* Webster [35] records it as a parasite of that well-known pest of stored cereals — the Angoumois Grain Moth (*Sitotroga cerealella*). Other recorded hosts are the Peach Twig Borer (*Anarsia lineatella*, Zell.) in America; and Marlatt has observed this mite feeding on the eggs of the Periodical Cicada or Seventeen-year Locust [36]. It has been noted as a parasite of the Bean Beetles (*Bruchus quadrimaculatus* and *B. chinensis*) by Chittenden. The species is known as a parasite of the Mexican Cotton Boll Weevil (*Anthonomus grandis*, Boh.) in Mexico, and it was imported from there into the United States of America in the hope that it might prove an important enemy of this notorious pest then causing such havoc in Texas. However, this hope was unfortunately doomed to disappointment. It is of interest to quote Messrs. W. D. Hunter and W. E. Hinds [37] on the question of the mite as a weevil parasite, since the problem of the boll weevil in America and the pink bollworm in Egypt have many similar aspects. These authors say (page 147) :—

« In the course of these experiments the possibility of the mites attacking larvæ, pupæ, or immature adults was tested. The observations made failed to show any positive ability on the part of the *Pediculoides* to penetrate the squares, as in only two cases were mites found in them and attacking the larvæ. In these two cases it seems entirely possible that the mites may have entered through the feeding punctures or some other rupture in the floral envelopes. »

« Upon several occasions during the season of 1903 mites were distributed in badly infested cotton fields. Later examinations were carefully made, but failed to show that the parasite had gained a hold or even that they had attacked the weevils in any stage. »

« These mites, if, indeed, they are the same species as those described by Newport, are widely distributed and attack, to some extent, quite a large number of insects. If they

really possessed the ability to get at the weevil larvæ and the predisposition to attack them when they could get to them in preference to other hosts, they should certainly have shown something of these capabilities somewhere within the infested area in Texas during the ten years that the weevil has been found there. As no such ability has yet been shown, we doubt if the *Pediculoides* will ever prove of any value as a parasite of the Weevil in the United States, though it may be more efficient in more southern countries. Furthermore, it is said that even where the mites do become established they are so subject to the attacks of small ants that their efficiency becomes largely destroyed. »

P. ventricosus has been observed to feed on the larvæ of wasps [38] and also of the Pepper Weevil (*Anthonomus eugenii*, Cano.) [39]. This mite is a well-known natural enemy of the Wheat-Joint-Worm, *Isosoma tritici*, in the United States and it is in its relation with this insect that some of the best known and most interesting outbreaks of skin trouble amongst human beings have taken place.

In Braun [40] it is stated that these animals, meaning *Pediculoides;* live on the stalks of cereals, and feed on vegetable and animal juices. Other authors, however, do not appear to have observed the vegetarian habits of this species.

In Egypt, in addition to the pink bollworm, this mite has been found on the pupa of a beetle, *Sphenoptera trispinosa* [41], the larva of the ordinary bollworm, *Earias insulana* [42], the pupa of the cotton worm, *Prodenia littoralis* [43] and also on the Cow Pea Weevil, *Bruchus chinensis* [44].

DESCRIPTION AND LIFE-HISTORY.

Pediculoides ventricosus is viviparous, and at birth the young mites already possess their fourth pair of legs and are sexually mature. The female mite produces eggs, but these hatch and the subsequent larval stage is passed within the body of the parent. Soon after birth the sexes pair and then the young female searches for a host, which may be the same as that on which the parent is feeding or a fresh one. The males are to a very marked degree much less active than the females; also they seem inclined to remain on the body of the parent female or in close proximity to it.

The male mite (Fig. 3, G) is oval in shape, flattened ventrally and somewhat convex dorsally. In length it measures about 0.22 mm. by 0.12 mm. in breadth. It is thus an extremely small creature and only with difficulty visible to the naked eye. On the dorsal surface there are four pairs of strong chitinous hairs. The legs are also provided with stiffish hairs. The first and fourth pairs terminate in small claws; the second and third are armed with a sucking pad and two small hooklets

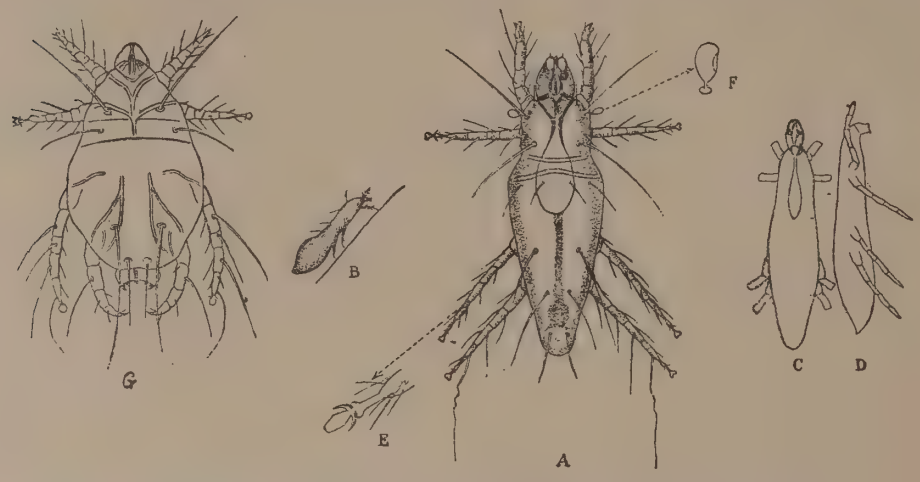

Fig. 3 *. — *Pediculoides ventricosus*, a predaceous mite parasitic on the pink bollworm.

(Fig. 3, E). In colour the males are pale yellow, with a pale band across the body behind the second pair of legs. The skin of the body and legs is polished and glistens.

The female in a non-gravid (Fig. 3, A) state is rather larger than the male, and instead of being oval it is somewhat shuttle-shape in form. At this stage it is about 0.32 mm. long by 0.12 mm. broad, thus like the opposite sex, it is almost microscopic. On the dorsum there are two pairs of conspicuous chitinous hairs which arise from the thoracic area of the body, and seven pairs of short or much shorter and less conspicuous hairs on other parts of the dorsum. The legs are strong and hairy; the second,

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* Reproduced by permission, from *The Agric. Journal of Egypt*, Vol. IV, Part I, 1914. Original drawing.

third and fourth pairs are provided with a sucking pad and two small hooklets (Fig. 3, E). The first pair has a small terminal claw but no sucking pad; these front legs appear to be used more in the nature of sensory organs than for locomotion, and when the mite is at rest they are elevated just off the surface and are held out in front of the head. From the last joint of the fourth pair of legs there springs a characteristically long hair with a twist or curl in it; these legs seem to be little used and are dragged along rather than moved when the mite is in motion. Just posterior to the first pair of legs on each side of the body there is a small clear bladder-like appendage (Fig. 3, F) — the pseudostigmatic organ.

The enlarged drawing shows the female mite as it appears mounted in glycerine and covered with a glass cover-slip. This treatment slightly alters the contour of the body (the same applies to that of the male). The diagrammatic outline drawings (Fig. 3, C and D) give a better idea of the shape of the mite as seen from above and from the side respectively. The head is very flexible in an up-and-down direction, and when feeding it is sometimes bent almost at right angles to the body.

Soon after the young female mite has left the body of the parent she commences to feed either on the same host or she may have to find a fresh one. Searching for a host is a critical time in the life of these tiny creatures, since it appears to have been established that they only live a short time without food — less than a day. Before settling down a young mite may feed in a number of places on the same pink bollworm. After feeding for a day or so the abdomen begins to swell and becomes somewhat lemon-shaped (Fig. 3, B). When this takes place the mite becomes more sluggish and much less ready to move about, but it can and does shift its position if so minded after the abdomen has reached quite an appreciable size. The abdomen continues to enlarge owing to the development of the eggs and young mites within until it is quite spherical in shape and many times larger than the rest of the body. The diameter may vary from 1.1 mm. to 1.5 mm., the latter being about the size of the head of a small pin, and thus from being an almost microscopic

creature the might develops into quite a conspicuous object, especially when there are perhaps more than a 100 of these gravid females on a single host (Plate VII, Fig. 11), such as the pink bollworm. The female (Plate VII, Fig. 12) at this stage is of a pale yellow colour, regularly or irregularly mottled with yellowish-white. Sometimes there are well-defined and large areas of brown on the abdomen. The skin is polished and glistening, also translucent. At this stage the female does not move about; it is only in the young non-swollen condition that she is so active, and it is at this period also, during the search for a host, that she may accidentally attack human beings.

The engorged females bear some resemblance to the eggs of insects, and on some occasions they have been mistaken for the eggs of those insects on which they have actually been present as parasites.

As regards the number of young produced by a single female mite, Wildermouth[44] found that it varied from just a few to 270. The largest number that he found produced in any one day was fifty-two. This author also observed that for a temperature of 90° to 100° F., six days elapsed from birth to the time the mite commenced to give birth to young. From 80° to 90° F., it was seven days, and from 70° to 89° nine days, from 60° to 70° thirteen days, and for a temperature lower than 50° F. it was thought doubtful whether the mites would develop. The ideal temperature for rapid development with the maximum production of offspring was found by Wildermouth to be between 70° and 80° F. In Egypt during the winter — January and February — it takes about six weeks for a larval mite to reach maturity and give birth to offspring. This period may be prolonged if the weather is cold as then the young remain in the body of the parent.

With regard to the effect of temperature on the activity of the mites, Webster[45] says :—

« Like the larvæ on which they subsist, their development is retarded or increased by temperature, they being quite active at a temperature of 60° F., but in colder weather able to remain within the abdomen of the parent for months in a dormant state, awaiting a rising temperature. »

A single pink bollworm is sufficient to nourish a very large number of mites; for example, in three cases observed the following numbers of well-grown mites were removed from pink bollworms :—

No. 1	125	mites.
No. 2	123	—
No. 3	160	—

It can thus be readily understood that when each of these mites produces several hundred young in the course of quite a short time the increase of the creature is very rapid.

Gelechia larvæ infested with this parasite undergo a marked colour change, the ground colour of the body turning to a distinct orange-yellow or orange hue, the pink markings persist however. The site of the feeding punctures of the mite are often marked by a circular dark brown or black spot and sometimes black rings. By these indications it is generally quite easy to determine whether a dead pink bollworm has been killed by mites, although none of these parasites may be actually present at the time of the examination.

PEDICULOIDES VENTRICOSUS IN EGYPT AND ITS UTILITY AS A PARASITE OF THE PINK BOLLWORM.

The mite was first observed as a parasite of the pink bollworm in cotton seed obtained from Alexandria in April 1913. It was not, however, numerous at this season in the samples received. An examination of ninety-one « double seeds » picked from the above gave the following results on examination as regards the number of pink bollworms which had succumbed to the attacks of *Pediculoides* :—

Sample A.

Number of double seeds examined	91		
Number of seeds containing pink bollworms	68		
Number of seeds containing live pink bollworms	54	or 79.4	per cent.
Number of pink bollworms killed by *P. ventricosus*	10	or 14.6	—
Number of pink bollworms dead from? disease	4	or 6.0	—

On April 22nd a sample of cotton seed was received from Behera Province. This sample contained a very large number of pink bollworms, six per cent of the seed being infested. Mites were present : a sample of 213 double seeds hand-picked from this Behera seed showed the following mortality due to mites amongst the pink bollworms :—

Sample B.

Number of seeds	213	
Number of pink bollworms in seeds	147	
Live pink bollworms	112 or 76.2	per cent.
Pink bollworms killed by *P. ventricosus*	17 or 11.5	—
Pink bollworms dead from? disease	18 or 12.3	—
Seeds containing no larvæ	52	

A lot of several hundred double seeds from this same sample examined about the third week in May showed that out of 391 larvæ found in the seeds 148, or 37.8 per cent, had been killed by Pediculoides. It should be pointed out, with regard to this last sample, that the seeds had been lying together in a mass and thus the mites had not far to search for a fresh host; moreover, the seed had been soaked in water and the temperature was also rising, two factors very beneficial to the increase of the parasite. Still another examination of this same seed during May showed the following mortality due to attacks of this Acarus on the *Gelechia* larvæ :

Sample C.

Number of seeds examined	592	
Number of pink bollworms found	468	
Pink bollworms killed by mites	58 or 12.3	per cent.

In the case of sample C, the double seeds had been lying together in a mass, but they had not been soaked.

As regards the abundance of mites in seed from the 1913 cotton crop the following figures are of interest :—

Sample D.*

Number of double seeds	155
Number of pink bollworms found	132
Number of pink bollworms killed by *P. ventricosus*	2 or 1.5 per cent.

Sample E.*

Number of double seeds examined	4,380
Number of pink bollworms found	3,442
Number of pink bollworms killed by *P. ventricosus*	46 or 1.33 per cent.

Another sample gave the following :—

Sample F.*

Number of double seeds	800
Number of live pink bollworms	454
Pink bollworms killed by *P. ventricosus*	5 or 1.1 per cent.

In March 1915 an examination of 240 double seeds picked out from a large sample of refuse cotton seed gave the following results :—

Sample G.

Number of seeds examined	250
Number of pink bollworms found	215
Number of pink bollworms killed by mites	10 or 4.6 per cent.

In May 1915 the mortality from *P. ventricosus* in a sample of the same seed was as follows :—

Sample H.

Number of double seeds examined	507
Number of pink bollworms found	411
Number of pink bollworms killed by mites	50 or 12 per cent.

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* Samples D, E, F were examined December-January 1913-1914 and were received from the State Domains, Sakha.

So far this mite has never found in green unripe bolls infested with pink bollworms, but it has been found in dead cotton bolls collected from the farm of the Agricultural Society at Bahtim, Chubra. However, the mites were not common in 250 bolls examined; 372 pink bollworm larvæ were found, and of these 5, or only 1.3 per cent, had been destroyed by *P. ventricosus.*

Now as regards the importance of this mite as a natural enemy of *Gelechia gossypiella*, the writer has already expressed the following opinion on this question in a previous paper [46] :—

« At first I hoped that this mite might be an important enemy of *Gelechia gossypiella*, but now I doubt if it can do very much in this direction. To be effective it must be able to easily attack the pest in the field, but its powers of doing this, judging by its work against the Mexican cotton boll weevil, seem likely to be very limited. However, it may be more effective in the case of pink bollworm passing the winter and spring in the dead cotton bolls on the heaps of cotton sticks in the fields and on the roofs of houses, but this remains to be proved. Now as regards its importance when it attacks the pink bollworm in cotton seed : for rapid increase it seems to require a fairly high temperature, and this required temperature is not reached until after all, or at any rate the bulk of cotton seed has been sown, and, moreover, we have found that the best taqâwi contains very few seeds infested with the pink boll worm; thus the mite would have difficulty in meeting with its host. The low grade badly infested seed is mostly exported from Egypt for crushing, and therefore the destruction of the pink boll worm in such seed is not of very great importance to this country. »

As yet there seems to be no reason to materially modify the opinion expressed above. We are still in the dark as to what extent the mite is able to attack the pink bollworm in the field when it is feeding inside a boll. The probability is that it can do so only under very favourable conditions. No case of a larva destroyed by mites has been found in the green bolls that have been examined in this laboratory during 1912 to 1915. This tends to show that the mite finds it exceedingly difficult to penetrate into a green boll and in fact the only chance of its doing so would be through a crack in the shell caused by proliferation, or by way of an exit hole left by a pink bollworm; or again, possibly at the apex of the boll where the divisions meet.

The finding of *Pediculoides* on *Gelechia* larvæ in the ripe damaged bolls is proof that it is capable of finding and attacking its host in the field, but so far we have no positive evidence to tell us that this is by any means an easy feat for the larval mite to accomplish; in fact the absence of information shows rather the contrary, otherwise one would expect to find the mortality amongst the pink bollworms very much higher indeed in the damaged bolls than is actually the case, and also in the newly ginned seed.

As an agent for greatly reducing the number of pink bollworms in the cotton seed used for sowing no reliance can be placed on the *Pediculoides,* owing to the temperature not being high enough in November and during the winter for its rapid multiplication. As proof of its failure in this respect we have the examination of tagawi and other samples of seed (see Table XLI) in March — the month for sowing cotton — showing that the seed was still full of live pink bollworms in spite of the presence of mites.

Cotton seed infested with the pink bollworm kept in my laboratory during the summer of 1914 was swarming with young mites by the end of June. One would think therefore, that it should be of considerable benefit in destroying *Gelechia* larvæ in any stocks of cotton seed and seed-cotton remaining in the Provinces up to this date or later. But as we shall see this is by no means certain.

In 1915 a half sack of cotton seed very badly infested with pink bollworm was kept under observation in the laboratory. By the end of June the seed was alive with young mites and then all of a sudden, in contrast, they may almost be said to have disappeared; but why they did so was not apparent. In July, hundreds of the resting pink bollworms left the seed and pupated outside the sack unmolested by the mites. In this case then, when the pest was most open to attack and the mites were most needed they were not there to carry on their useful work — so often the case with natural enemies! It is true a few mites were present and a few larvæ succumbed to their attacks here and there, but the great majority of the pink bollworms issuing at this time gave rise to moths.

Possibly the temperature in July and August is too high and the atmosphere too dry for the normal increase of *P. ventricosus*. This observation is of great interest as it demonstrates the fact that a sample of seed may be swarming with young mites — one might almost say with millions of them — and yet large numbers of pink bollworms escape their attacks. It would seem probable therefore, that these Acari are able to reach only those larvæ which are insecurely spun up in the seeds, a really well and closely woven cocoon is impenetrable to even such a small creature as the unfed *P. ventricosus* female. Thus this mite cannot be relied on to remove the danger of the resting pink bollworms in cotton seed nor in the dead bolls in heaps of cotton sticks; on the other hand, the danger is no doubt reduced, but to what extent I cannot say.

From another point of view, the presence of numerous young mites in cotton seed that has to be handled for export may be a decided disadvantage owing to the habit the young mites have of biting human beings when they come in contact with them and the effect of their bites, which cause an outbreak of a rash on the skin. In the case of most persons this attack gives rise to great irritation and sometimes more serious symptoms. An outbreak of this skin trouble occurred at the London docks in 1913-1914 amongst labourers engaged in discharging cargoes of Egyptian cotton seed shipped from Alexandria [47].

As regards the utility of the mite as a means of reducing the pink bollworm in damaged bolls left on the sticks that are stored on the housetops and in heaps in the field we have no information at present. One would expect that during the course of the summer considerable mortality might result from this cause, but it is evident, from the results shown in Table XXXIII, that *P. ventricosus* by no means exterminates the pink bollworm in these situations and at this season. It would seem probable that the mite will have greater difficulty in finding a fresh host in the case of the cotton sticks than in a heap of seed.

THE OCCURRENCE OF A STAGE OF A RHIZOGLYPHID MITE ON THE PINK BOLLWORM.

A mite of characteristic appearance was observed in large numbers on pink bollworm larvæ that emerged from the boxes containing infested cotton bolls buried in soil (*vide* page 165). Quite a number of the pink bollworms were smothered on certain parts of the body with these acari which cling very closely, applying themselves chiefly to the head, the thoracic shield and the thoracic legs; they were also present on other parts of the body but not so thickly.

Although the hosts seemed fairly strong it was evident that in a number of cases their usual freedom of movement was much hampered by the presence of their numerous and no doubt unwelcome guests.

These Acari, which I took to be the hypopal stage of a *Rhizoglyphus*, were more or less oval in form, slightly pointed at the head, and with the dorsum convex and highly polished. The colour was brownish or brownish tinged with a violet or purplish shade.

This stage in the life of a *Rhizoglyphus* attaches itself to an active and wandering host such as a caterpillar, not as a true parasite, but as a vehicle by which it may be transported to a fresh locality and feeding ground.

Some pink bollworms embarrassed with the mites were kept under observation : they finally died, but I was unable to determine whether their death had been brought about by the mites or by other causes — I think the latter.

The Rhizoglyphids may have been in the soil feeding on dead matter or in the rotting bolls.

The hypopal stage of the common *Rhizoglyphus echinopus* has been recorded on the larvæ of the potato moth (*Phthorimæa operculella*, Zell.) by F. Picard *. *R. echinopus* occurs in Egypt and thus the mites present on the pink bollworms may well have been the hypopal stage of this species.

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* La Teigne des pommes de terre, par F. Picard : *Annales du Service des Épiphyties*, 1912, page 137 (Ministère de l'Agriculture, Paris 1913).

SPIDERS AS ENEMIES OF THE PINK BOLLWORM.

As yet no serious study has been made of the spiders as regards their relation to the pink bollworm. It is thought, however, that these creatures are of importance — perhaps of great importance — in reducing the numbers of the undesirable insects which inhabit cotton fields where the useful spider fauna is by no means inconsiderable, some species living on the plants, others on the ground. A number of families are represented, but only the more important ones are mentioned here.

A medium sized somewhat pallid species (? Family Palpimanidæ) — shown enlarged at Fig. 4 — may be fairly common in cotton fields. This species has the cephalothorax and the legs of a pale brownish-ochreous hue, but the tips of the tarsi are dark. The chelicerae are very powerful, black in colour and polished. The pedi-palps are of the same hue as the legs, except for the terminal joint which is dark; in the males this point is tumid or swollen. The abdomen is large, oval in form, cylindrical in section. In colour it is pale greyish-green or greenish-ochreous profusely flecked with minute pallid spots. The surface is covered with numerous short fine hairs, but at the same time it is shiny, especially on the ventral surface. The spinnerets project well beyond the tip of the abdomen. A very characteristic feature of this spider is the great length of the first pair of legs compared with the other three pairs. This character is especially noticeable when this spider is quite small.

Fig. 4. — A Cotton Plant Spider (? Family Palpimanidæ). Enlarged about 1 $\frac{1}{2}$ times.

This species lives in a pouch-like or more or less tubular structure very closely woven of fine greyish-white silk spun within the shelter of the

involucre of squares, flowers and bolls, or sometimes between two leaves or a folded over leaf. In this retreat, which is frequently renewed in a fresh location, the spider remains hidden during the daytime, but at night it emerges to seek its prey. The exact manner in which it makes captures has not been observed, but it spins, so far as I know, no silken snare or web for this purpose; possibly the long front legs are brought into play for seizing the victims. This species has long been known to feed on the moths of the bollworm *Earias insulana*, and no doubt it feeds also on *Gelechia gossypiella* and any other moths it can catch and master. In captivity it feeds readily on the pink bollworm, both larvæ and moths.

A quite small spider (? Family Theridiidæ) is shown enlarged at Fig. 5. This and several similar species are often quite numerous in cotton fields. They spin a web composed of a collection of silk threads arranged in no definite order within the involucre of a boll, square or flower, between two bolls; also at the base of a leaf where the palmate veins arise from the leaf stalk, or again, in the fold formed at the juncture of the apical lobe with the lateral lobe of the leaf.

Fig. 5. — A Cotton Plant Spider. Enlarged about 4 times.

The appearance of the species shown at Fig. 5 is as follows : Abdomen globular and ornamented, the colouring in browns of various shades and creamy whites or buffs being arranged in the form of a definite pattern. The cephalothorax is yellowish-brown; the legs are of the same hue banded at the joints with dark brown or blackish.

These small spiders have been observed in the field to feed on the young stages of the cotton worm (*Prodenia litura*, Fab.); probably they feed also on the newly hatched pink bollworms when the latter are wandering about in search of a boll to bore into. In captivity these spiders take these larvæ quite readily. Ants and perhaps Aphids also form part of their diet, but sometimes where the former are numerous — as for instance in gardens, they turn the tables and feed on the spider.

Figure 6, shows a spider belonging to the family Agelinidæ which has been abundant this season (1915) among cotton plants growing in the laboratory garden and since it feeds readily on the pink bollworm it is mentioned here. Unfortunately however, these spiders do not seem to occur in cotton fields for some reason or other; in fact they seem to be very rare in the agricultural land, at any rate in some districts. One may go miles without seeing a sign of them and then perhaps on a quiet canal bank there will be quite a colony of their sheet-like webs of grey silk.

Fig. 6. — A Funnel-web Spider or Agelinid. Enlarged about 2 $\frac{1}{2}$ times.

This Agelinid is a fair-sized powerful species. In colour it is fuscous, but the legs and cephalothorax are much paler than the abdomen. The cephalothorax is ornamented with a pattern in pale hairs and the abdomen is adorned with dark and pale patches or tufts of hairs, some of which are white and form conspicuous white spots and in some specimens irregular wavy white lines on this part of the body. The legs are hairy and are also armed with a number of spines. The eyes are black, eight in number, arranged in three transverse rows. The spinnerets project beyond the tip of the abdomen.

The densely woven sheet-like webs of these spiders are spun close to the ground amongst and supported by the herbage, fallen leaves, etc. In addition there is often an aerial portion to the web. This consists of silk threads spun apparently at hazard, crossing and re-crossing each other

without a definite arrangement. To one side and sometimes almost in the middle of the sheet-web there is a tubular way, formed of silk also, opening on to the upper surface and leading from there down to the ground amongst the dead leaves, etc. At the bottom of this retreat, well hidden from view, the spider proprietor of the web lives and waits its prey. When an insect falls into the sheet of silk — say for example a full-grown pink bollworm which has just cut its way out of a boll, and falling from it to the ground has landed instead on to the soft snare of our Agelinid — the spider immediately runs up the funnel-like or tubular way leading on to the upper surface of the web, seizes the victim and retires with it to its hiding place to feed at leisure.

In feeding pink bollworms to this spider I have noted that ants will invade the webs and carry off the larva peacemeal, the spider not daring apparently to interfere with the little thieves — at all events in the cases I observed.

The Thomisidæ or Crab-spiders are represented in the cotton fields by a very handsome greenish or yellowish species (Fig. 7) marked with brown. The posterior part of the abdomen bears two breast-like tubercles marked with brown : these do not show when the eggs have developed and the abdomen of the female is much swollen in consequence. Unfortunately this spider appears to be uncommon. Little is known of its habits, but in captivity it will feed readily on the moth and larval stages of the pink bollworm which are seized with the two front pairs of legs. The position in which the latter are held remind one strongly of the chelæ of a crab; it is of course the position in which the legs are placed and the side-way movements of these spiders that has given rise to their family name of Crab-spiders.

Fig. 7. — A Crab-Spider.
Enlarged about 4 times.

Being a diurnal species it is doubtful if it often meets with the pink bollworm except when the latter has recently emerged from the egg and

is crawling about over the plant in search of a boll. The female spins a cocoon of white silk in which to lay her eggs. In captivity the mother appears to be very amiably disposed towards her offspring and although she may have been without food for days makes no attempt to devour them. The female does not die nor apparently lose strength after laying eggs — at any rate one batch of eggs. The young spiders are interesting as they practice the so-called ballooning method of dispersal. Seeking an elevated position — such as a leaf on the upper part of a cotton plant — they spin a small light mass of silk; this is carried away to leeward and pulls out with it (at the will of the individual) a thread of silk from the spinnerets. When the lifting power of this primitive flying apparatus is sufficient, the spider leaves go its hold on the leaf and shoots away on an aerial voyage, the object of which is to carry it to fresh feeding grounds and to bring about the dispersal of the species over a wider territory.

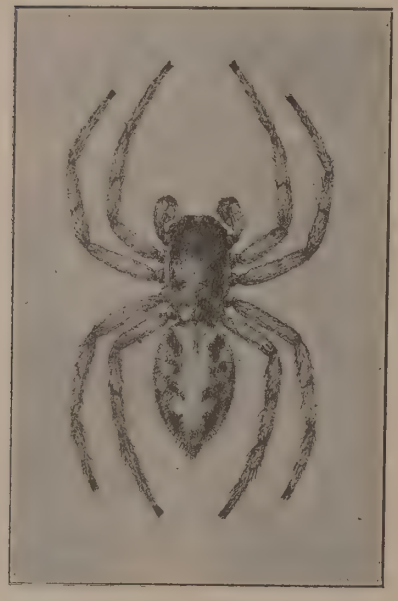

Fig. 8. — An Attid or Jumping Spider. Enlarged about 4 times.

Several members of the Lycosidæ or Wolf-spiders and *Lycosa*-like spiders are common in and around the borders of cotton fields. However, as the majority of them do not appear to be particularly powerful species it is not by any means certain that they would be able to master a full-grown pink bollworm.

In cotton and cotton-seed stores members of the family Attidæ or Jumping spiders (Fig. 8) may be found. They feed on the pink bollworm both in its larval and moth stages. These spiders are very characteristic and can be very easily recognised by their compact and powerful form and legs, and the four eyes placed on the *front* of the head, the two middle eyes being very much larger than the lateral ones. On the *top* of the head there are four more eyes, two very small ones in front and two

larger ones behind these. The jumping powers possessed by these spiders are, when they are alive, alone sufficient to identify them. Their colouring is often brilliant. It cannot be said, unfortunately, that they are common in the situations mentioned.

A number of small Attid spiders measuring only some 3 to 4 mm. in length occur, but not in great numbers, on cotton plants; especially at the end of the season in the bollworm damaged bolls where they seem to feed on the numerous Psocidæ present in this situation. When free on the cotton plants it is possible that they might take newly hatched pink bollworms.

These tiny Jumping spiders are extremely pretty, some being metallic bronze, others are of a bright metallic coppery hue and still other species are bright metallic black adorned with brilliant white spots on the abdomen and sometimes on the thorax. The legs are pale yellowish or in some a delicate amethyst shade. Other species are clothed with pale golden hairs, and yet others are more sombre owing to their covering of short greyish hairs of different shades so arranged as to form a pattern.

Fig. 9. — The Store Spider — a cobweb weaver. Enlarged twice.

A spider very common in stores is a member of the family Pholcidæ. This curious creature is shown at Fig. 9; it is chiefly remarkable for its extremely long and thin legs. These spiders spin irregular webs, sometimes more or less sheet-like in the angles made by the walls, amongst

the rafters and beams of the roof trusses, about windows and between sacks and bales. They feed on flies and small moths, etc., and no doubt many pink bollworm moths are destroyed by them in cotton and cotton-seed stores.

BIRDS AS ENEMIES OF THE PINK BOLLWORM.

So far little attention has been paid to this question but I am afraid that birds can but play a minor part in the control of the pink bollworm. Birds are not often seen in cotton fields except perhaps just at the commencement and again towards the end of the season when the damage by the pest will have reached its worst : but even at this time they cannot be said to be numerous either in numbers or species.

The Crested Larks (*Galerida cristata*) may be seen in cotton fields recently sown or whilst the plants are still small, and it is possible that at this season they pick up pink bollworms which have left their quarters in the cotton seed (owing to the watering and wetting of the soil) and come to the surface to pupate.

As the plants grow up the crested larks seem to abandon the cotton fields altogether.

In the autumn Chiffchaffs (*Phylloscopus collybita*) arrive in Egypt to pass the winter and may be commonly observed in cotton fields at this time of the year busily flitting from plant to plant and feeding on insects — aphis, etc., etc. No doubt pink bollworms are included in their diet when seen — as regards this point I am inclined to think that the small newly hatched pink bollworm would be more likely to fall a victim to the keen eyes of these pretty little birds, which seem to be more often picking things off the leaves, stems and branches of the plants rather than feeding on the ground.

Sparrows (*Passer domesticus niloticus*) have been seen to feed on pink bollworms crawling about in stores and I have also seen them in the laboratory garden feeding on the resting larvæ which have left sown and watered cotton seed to come to the surface and pupate. Crows (*Corvus*

cornix) have been observed to take pink bollworms under the same conditions.

TOADS AND FROGS.

The role played by toads and frogs in cotton fields as regards their relations towards the pink bollworm require investigation. Their value is not altogether certain since they eat injurious and useful insects indiscriminately.

PARASITIC INSECTS.

THE PINK BOLLWORM PIMPLA.

This insect first came under the writer's notice in December 1912, two females being bred from a large number of bolls (received from the Society's Farm at Bahtim, Choubra) which were infested with *Earias insulana* and *Gelechia gossypiella*. This observation was recorded in the Bulletin de la Société Entomologique d'Égypte under the title of « An Ichneumon Fly Suspected of being a Parasite of *Earias insulana* — the Cotton Bollworm » [48]. However, during the discussion following the reading of this note at the meeting of the above Society; Dr. Gough, Entomologist to the Ministry of Agriculture, was able to point out that this insect — later identified as *Pimpla roborator*, F. — was really a parasite of the pink bollworm.

In 1913, *P. roborator* from a rare insect increased to such an extent as to become quite common, being present in numbers in cotton stores and ginning factories, where the adult insects were found crawling on the windows and about the unginned cotton. A considerable number were bred from bolls picked on the Society's Farm in November, but the parasite was not noted in the fields.

As regards the status of *P. roborator* in 1914, it did not appear to have increased to any great extent at Bahtim; in fact it seemed if anything to be rather less numerous in the bolls received from there, but this impression may quite probably have arisen from the fact that a smaller number of bolls were handled in 1914 than in 1913.

It is to be hoped that this *Pimpla* may increase in the future*, since from a mechanical point of view it is the one parasite we have that appears really suited to successfully attack the pink bollworm, owing to the female being armed with a long ovipositor with which to reach the larva even when it is well in the interior of a boll. Unfortunately however, this insect, as will be shown in due course, works under certain disadvantages, and moreover, it has a number of bad habits which it is feared may seriously check its usefulness as a natural control agent of the pink bollworm : therefore no great hopes must for the present be built on the help to be expected from its work.

In February and March of this year (1915) the *Pimpla* was noted as being quite abundant in the laboratory garden (Ghezireh, Cairo) flying about and ovipositing in dead cotton bolls, which had been strung on strings and exposed to the sun. On one occasion (February 23rd) as many as sixteen of these insects — all females — were caught in a morning; no males were seen until the new generation emerged. This proved the opportunity for a considerable amount of information to be obtained regarding the habits and immature stages of this parasite which, so far as I am aware, has not hitherto been recorded.

PAST HISTORY OF *PIMPLA ROBORATOR.*

Although known since a long time — having been first described by Fabricius — little or nothing appears to have been written about the habits and immature stages of *Pimpla roborator,* and hitherto our knowledge has been confined to the association of this parasite with several hosts belonging to widely different natural orders. Ratzeburg[49] quotes Gravenhorst as having bred it from *Tortrix turionana* feeding on spruce buds and also himself records it on this host.

Schemedicknect[50] states its habitat to be Thuringia, Andalusia and

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* November 23rd, 1915. P. roborator has undoubtedly increased during the past season and is more numerous at Bahtim than ever before.

Algeria. The most important information he gives relates to the hosts of the species which include *Sesia formicæformis* and *Sesia spheciformis* of the order Lepidoptera, *Cyrptorhychus lapathi* (Coleoptera) and *Nematus gallarum*, a saw-fly (Hymenoptera). It thus appears that *P. roborator* is very impartial in its tastes to be parasitic on members of no less than three different natural orders. No doubt in Egypt we shall find it has several hosts, since all three genera in the above orders occur here.

DESCRIPTION OF THE FEMALE AND MALE *P. ROBORATOR.*

The female. — The female (Plate V, Fig. 3) of this species is a handsome insect, coloured in black and dark reddish-brown, and conspicuous because of the ovipositor which is about the same length as the body. A well developed female will measure from the head to the tip of the ovipositor from 17 mm. to 20 mm. with a wing expanse of 16 mm. Other specimens may be smaller — 18 mm. or less.

The head and thorax are black, antennæ black except the apical third which is obscure piceous, eyes black, occelli red. The thorax is punctuated. Wings faintly brownish in colour; stigma dark with the inner costal angles pale or yellowish and outer paler than median area, veins dark. Legs ferrugineous, claws dark. Abdomen strongly punctuated, obscure red, darker towards the apex which is almost black. Apex of 2nd, 3rd and 4th visible abdominal segments black forming three narrow black rings on abdomen. Ovipositor sheath black, ovipositor ferrugineous.

Some females are darker than others and occasional individuals are almost black in colour.

The male. — The male (Plate V, Fig. 4) measures from 7 mm. to 10 mm. in length with a wing expanse of 14 mm. The colouring and punctuation similar to that of the female except that the colour tends to a darker shade. In some males the head, thorax and abdomen are black in colour. Legs ferrugineous. The male when crawling or at rest has a characteristic attitude owing to a tendency to elevate the tip of abdomen slightly. The male of course has no ovipositor.

LIFE-HISTORY AND HABITS.

Oviposition by the female. — Alighting on a boll, the female crawls slowly and deliberately over it, exploring the surface carefully with her antennæ which are curved downward from the middle and are kept in a constant and fairly rapid motion, gently touching the boll in a series of tappings. Having located a pink bollworm, she then raises herself on her legs and curves the tip of the abdomen round until the ovipositor is brought between the coxæ of the second and third pairs of legs to bear on the desired spot (Plate X, Figs. 7-8); the ovipositor sheath is now opened, the ovipositor released and the sheath returned to its normal position. The fine chitenous ovipositor which consists of three pieces is then thrust, by a downward or forward movement of the curved abdomen, into the lock of dead cotton in an endeavour to definitely locate and pierce the cocoon of the resting pink bollworm in order that the latter may be stung into insensibility and so prepared for the reception of the egg. Sometimes these efforts meet with success fairly soon, but at others the female is unable to reach the victim from the position she has taken up. In the effort to do so she may turn round and round the ovipositor acting as a pivot, but in most cases she will finally have to withdraw the ovipositor and select a fresh position from which to attack. In one or two cases noted the female has been observed to apparently excavate a hole removing the dead cotton and dry proliferation tissue from the lock piece by piece with her jaws and then thrusting the ovipositor into the hole so made in a further attempt to reach and sting the host. In such cases it is possible that the females were really intent on obtaining access to the pink bollworm to feed on it rather than for the purpose of oviposition.

During the preliminary work the ovipositor is drawn up and down a number of times, but when the egg is being laid the female keeps almost motionless except for slight muscular movements in the abdomen and perhaps an occasional upward and downward thrust of the ovipositor. The time required for the performance of the whole operation of stinging

the pink bollworm and laying the egg varies considerably, depending as it does on the difficulties lying in the way of the accomplishment of this act. It may take the female only a matter of about ten minutes to oviposit successfully on the host but on the other hand, it may take her more than an hour to do so.

After oviposition the female goes through an elaborate toilet washing the whole of the head, antennæ, and thorax with the front tarsi, which are drawn through the mouth to moisten them and remove the dust. The right foot is used to brush the left side of the body and *vice versa*. The hind legs clean the wings and abdomen, and the ovipositor sheath is drawn through the crossed hind tarsi or feet.

A female lays a single egg *on* and not inside the pink bollworm, which has of course first been rendered insensible by being stung. The egg is never attached firmly to the skin of the host; in fact in most cases it is simply deposited on the larva or perhaps even loosely inside the cocoon; at all events in removing «stung» pink bollworms from their cocoons the egg will generally be found to have fallen off during the removal and must be looked for in the cocoon or on the table at which the work is being performed.

In one or two instances captive females have laid two eggs on a host, but in these cases the eggs have been practically coalescent and thus in all probability were passed out together.

Females have been observed to sting pink bollworms without subsequently laying an egg on the victim.

Both in the laboratory and in the field cases have been noted when one female has attempted to interfere with another female already engaged in oviposition or the preliminaries thereof. The intruder would take up a position in front or at the side of the first and seemingly regard her operations with intense interest until suddenly she would advance on her with wings raised and even seize a leg in her jaws. The ovipositing female, however, paid little attention to these manœuvres and one or two beats of her wings was apparently a sufficient hint for the other to desist from interference and mind her own business.

Two and even three females have been seen to oviposit amicably in the same boll at the same time.

Faulty instinct of females when ovipositing. — Apparently the female is not in all cases able to tell for certain if a cotton boll does contain a pink bollworm or not, since they have been seen attempting oviposition in bolls which on subsequent examination revealed no sign of the pink bollworm other than that at some time they had been attacked and abandoned by this pest. Again, they have been noted to do so in bolls containing a dead and dried up pink bollworm or an empty pupa case of this species. It is true that no eggs were laid, but it is possible that I had disturbed the female before she had time to oviposit. On the other hand it is possible that the female has to rely on the ovipositor, which may be sensory, to tell her finally if a live pink bollworm is really present in a boll that her antennæ have led her to suspect is inhabited.

Sleep habits of the female. — The females have been noted asleep in the evening on the bolls about and in which they have been flying and ovipositing during the daytime, and apparently they may keep in the same spot for some days, for in the laboratory garden a female with one stylet of her ovipositor sheath peculiarly malformed was noted ovipositing on four consecutive days.

Mr. Andres informs me that he has observed in the desert wadys near Cairo numbers of females *P. roborator* congregating in the late afternoon to sleep on a plant known as silsila.

THE EGG.

Description. — The egg (Plate V, Fig. 6) of *P. roborator* is large measuring about 2 mm. or just over 2 mm. in length and 0.27 mm. in diameter at the middle, towards each end it tapers. In form, the egg is variable but generally speaking it may be likened to a rather straight calabash. Each end or pole of the egg terminates in an appendix-like

structure variable in form, being flat and scale-like, spatulate, hastate, or cylindrical. Cases have been noted in which the egg has been attached to the skin of the host by the appendix.

In colour the egg varies from a pearly or greyish-white to a distinct but pale yellow, the ends, however, are colourless and glassy in appearance. The shell is faintly striate, the appendixes being inconspicuously rugose.

Incubation period of the egg. — At a temperature of 65°-70° F. the egg stage lasts just under four days, but in an incubator run at 94° F. it required under 24 hours for the egg to hatch.

Hatching of the egg. — The young larva appears to burst its way through the egg shell at the broader end of the egg immediately below the «appendix». The bucal apparatus seems to be inflated or exerted and perhaps by this means the egg is ruptured. The young larva may commence to feed on the host before it is actually free of the egg shell.

THE LARVA.

The young larva. — The newly hatched larva is a little larger than the egg, colourless and glassy in appearance except for a median yellowish area. The head is large and bluntly triangular in form, slightly corneous in appearance; antennæ pale.

The mouth parts are brownish and chiteneous. Segmentation of the body well marked. Some larvæ are more of a pearly-white colour, the body being closely flecked with opaque white. The latter appearance depends mainly on the age of the larva.

The newly hatched larva can and does change at will its feeding position on the host larva; moreover, a larva of any age can be transferred from one host larva to another upon which it will feed successfully providing that the second larva has been stung by a *Pimpla*.

On the second day the larvæ become brownish owing apparently to

the absorbed contents of the host showing through the transparent skin, which is now conspicuously mottled with opaque irregular specks on the dorsum. The extremities of the larva remain colourless and glassy.

1st MOULT. — Growth proceeds somewhat slowly until about the sixth day when the larva changes its skin. Preparatory to this, the larva remains quiescent for a short period stretched out on its host; the bluntly triangular head and the segmentation of the body being very distinct.

After moulting the skin appears rougher in texture and the larva less glassy in appearance. Growth is a little more rapid after this moult.

2nd MOULT. — On the 8th day or thereabouts (at 65-70° F.) the larva moults a second time and then the skin is white and polished. Growth now proceeds with great rapidity and the entire contents of the host is quickly absorbed, nothing being left but the head and empty skin.

MATURE LARVA. — On about the 9th day the larva reaches full growth (Plate V, Fig. 7). It is now some 9 mm. to 10 mm. long and lies in a curved position. The body is apodal and tapers towards the ends. The skin is ivory white in colour and shiny, but the contents of the gut show through the skin along the dorsum and sides giving it a reddish or rather a plum-coloured tinge. This colour, however, gradually disappears. The head is conspicuous and marked with four dusky markings.

Although the skin is smooth and shiny to the naked eye, it will be found that under the microscope it is really thickly studded with minute papillæ.

THE COCOON. — When full grown, larvæ kept under observation span a cocoon of very fine and closely woven white silk an operation taking about 24 hours but sometimes much longer, since in an unnatural environment they often make several abortive attempts at cocoon construction before their efforts meet with success. Whether under natural conditions the larvæ spin cocoons within the cocoons or « double seeds », etc.

which protected their host is not known, but presumably they do so, since they are provided with the silk and necessary apparatus for carrying out this work.

Pre-pupal stage. — The cocoon finished, the larva becomes quiescent lying in a curved position. The body shrinks considerably in length and gradually changes from the ivory or yellowish-white colour to a distinct yellow. The body straightens out and gradually it becomes more and more like the shape of the pupa (Plate V, Fig. 9). The eyes of the future pupa are plainly visible through the larval skin.

Up to the present the larva has voided no solid excrement.

3rd moult. — On the 7th to 9th day since the larva ceased feeding or the 21st to 23rd day since the egg was laid, the 3rd and last skin is shed and the pupa disclosed; with the skin the larva voids a small quantity of black viscous excretory matter.

The pre-pupal or quiescent larva stage lasts from 7 to 9 days at 65°-70° F. In the incubator at 94° F. it was reduced to two or three days.

In exceptional cases the pre-pupal stage lasted 21 days.

THE PUPA.

The pupa (Plate V, Fig. 8) is of a pale yellowish hue and the various members of the body are clearly visible. The female pupa can be readily told from the male pupa by the ovipositor which lies curved over the back. In about five days the colour of the pupa begins to change owing to the pigment of the future adult being laid down in the skin. The eyes first become dark and the ventral part of the thorax blackish, this gradually spreads until the whole head, antennæ and thorax are black. Next the coxæ and trochanters of the legs gradually assume a ferrugineous hue and lastly the abdomen, femora, tarsi and ovipositor change to the normal colour of the adult.

From the time the first colour change takes place until the normal colouring is arrived at requires four or five days, but in the incubator at

94° F. the changes took place much more rapidly being completed in two days or less.

The shedding of the pupal skin. — On the 10th or 12th day from the time the pupal stage was assumed, or the 32nd to 34th day from the commencement (at 65°-70° F.), the pupal skin is shed and the perfect insect is disclosed. The insect, however, does not at once leave the cocoon, in which there is sufficient room for the development of the wings, but remains in it for about 24 hours and at the end of this period it eats a hole through the silk and makes its escape.

DURATION OF THE LIFE-CYCLE.

In the Laboratory during February and March at a temperature of 65°-70° the whole life-cycle from the time the egg was laid until the adult emerged from the cocoon occupied from 32 to 34 days, and in exceptional cases 45 days. There seems to be a tendency for the males to take a slightly shorter period than the females.

In the incubator at 94° F., the life-cycle took only about 12 days.

Out-of-doors in the insectarium the life-cycle lasted at this season (February and March) 27 to 32 days the same, practically speaking, as in the laboratory.

Table XLIX shows the duration of the life-cycle of a number of *Pimpla roborator* bred in the laboratory and the dates on which various changes took place.

DURATION OF THE LIFE OF THE ADULT PIMPLA.

The females and males which were bred in captivity did not live long — generally speaking from a week to ten days only — although they were provided with food in the form of diluted honey. Attempts to get them to breed were also unsuccessful, although some of the females were seen to attempt to sting larvæ and oviposit. Females caught in the garden and then caged did much better, living as long as a month and readily

ovipositing on pink bollworms in dead cotton bolls and in double cotton seeds. They took no notice of free pink bollworms. One female found in a seed capsule of teel in January lived six weeks, but only laid very few eggs which, however, were fertile. She was mated with a male found in a teel seed capsule on February 12th, but whether or not copulation took place is not known. The male lived about 10 days*.

DOES PARTHENOGENESIS OCCUR?

Parthenogenesis or the production of offspring without the aid of the male is such a common phenomenon in the Hymenoptera that it would not be surprising if it did occur in the case of *Pimpla roborator*. So far I have been unable to determine whether a female of this species can lay fertile eggs without mating with the male. About one female which did lay fertile eggs there was some doubt as to whether she had paired with the male *Pimpla* placed in the same cage. Virgin females of this species have been seen to attempt oviposition in pink bollworms in cotton bolls, but no offspring were subsequently bred; however, neither were they from the cages containing males and females that had been placed together and in which the females had also been noted as attempting oviposition.

At present then, we are not in a position to confirm or deny the occurrence of parthenogenesis in the case of this insect**.

CAN THE PIMPLA STING A PINK BOLLWORM IN AN UNRIPE GREEN COTTON BOLL?

This question has arisen in the writer's mind from the fact that so far the examination of tens of thousands of green unripe bolls and pink bollworms in the late summer and autumn months — when *Pimpla roborator*

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* Both males and females bred from cotton bolls in November 1914, have lived well in captivity. Many have lived six weeks and are still alive.

** December 1915. Since this was written I have obtained fertile eggs from a virgin female *P. roborator*.

Table XLIX.

THE LIFE-CYCLE O

N° OF INDIVIDUAL.	EGG LAID.	EGG HATCHED.	APPROXIMATE DURATION OF EGG STAGE.	LARVA MOULTED 1st SKIN.	LARVA MOULTED 2nd SKIN.	LARVA CEASED FEEDING AND COMMENCED COCOON.	DURATION OF FEEDING STAGE.	LARVA FINISHED COCOON AND BECAME QUIESCENT.
	1915.							
1	12 o'c. 14. II...	9 a.m. 18. II...	3 days 21 hours.	23. II. p.m.	25. II. a.m.	28. II.	10 days.	1. II. a.m.
2	12 o'c. 17. II...	10 — 21. — ..	3 — 22 —	"	"	3. III. a.m.	10 —	5. III. —
3	1 p.m. 17. II..	9.30 a.m. 21. II.	3 — 20 —	25. II. a.m.	"	2. — —	9 —	5. — —
4	12 o'c. 18. II...	9 a.m. 22. II...	3 — 21 —	"	"	7. —	13 —	"
5	17. II. p.m.	21. II. a.m.	3 $\frac{3}{4}$ days.	"	"	2. —	9 —	3. III.
6	17. — — ...	21. — —	3 $\frac{3}{4}$ —	"	"	2. —	9 —	3. —
7	18. — — ...	22. — —	3 $\frac{3}{4}$ —	"	"	2. —	8 —	3. —
8	18. — — ...	22. — —	3 $\frac{3}{4}$ —	"	"	5. —	11 —	6. —
9	18. — — ...	22. — —	3 $\frac{3}{4}$ —	"	"	"	"	"
10	17. — — ...	21. — —	3 $\frac{3}{4}$ —	"	"	"	"	"
11	18. — — ...	22. — —	3 $\frac{3}{4}$ —	"	"	"	"	"
12*	4. III. p.m....	6. III. 9 a.m...	1 $\frac{1}{2}$ —	"	"	8. III.	2 days.	9. III. p.m.
13*	9. — 11 a.m..	10. — 9 — ..	22 hours.	11. III.	12. III.	13. —	3 —	14. — —
14*	9. — — ...	10. — 9 — ..	22 —	11. —	12. —	13. —	3 —	14. — a.m.

* Kept in incubator

Pimpla roborator.

Larva sheds 3rd skin and becomes a pupa.	Duration of the pre-pupal stage.	Total duration of the larval life.	Pigmentation of the pupa commences.	Pupal skin shed perfect insect appeared.	Duration of the pupal stage.	Perfect insect emerged from cocoon.	Number of days perfect insect remained in cocoon.	Total duration of life-cycle.	Sex of individual.
9. III.	8 days.	18 days.	14. III.	21. III. a. m.	12 days.	22. III. p. m.	1 day.	36 days.	Female
11. III. a.m.	8 —	18 —	16. —	22. — —	11 —	23. — —	1 —	34 —	—
9. — —	7 —	16 —	14. —	19. — —	10 —	21. — —	2 —	32 —	Male
23. — —	16 —	29 —	»	»	11 —	3. IV.	»	44 —	Female
11. — —	9 —	18 —	16. III.	22. III. a. m.	11 —	23. III.	1 day.	34 —	—
24. — —	22 —	31 —	»	2. IV. —	9 —	3. IV.	1 —	45 —	—
9. — —	7 —	15 —	15. III.	20. III. —	11 —	21. III.	1 —	31 —	—
12. — —	7 —	18 —	17. —	22. — —	10 —	23. —	1 —	33 —	Male
10. —	»	16 —	14. —	19. —	9 —	20. —	1 —	30 —	—
22. —	»	29 —	»	»	10 —	2. IV.	1 —	44 —	Female
10. —	»	16 —	»	19. III.	9 —	20. III.	1 —	30 —	Male
12. —	4 days.	6 —	15. III.	17. —	5 —	18. —	1 —	13 $\frac{1}{2}$ —	Female
16. —	3 —	6 —	19. —	?	5 —	21. —	?	12 —	Male
16. —	3 —	6 —	18. —	21. III.	5 —	21. —	?	12 —	—

t 35.5° C.

should be most common — has not revealed this parasite in any one of its stages. It has only been found when dry and dead bolls have been examined and then in comparatively few cases only. The Pimplas bred accidentally in captivity have always emerged from large numbers of bolls picked in November — at the end of the cotton season — and amongst these there is of course a very high percentage indeed of ripe damaged bolls from which it has been impossible to pick the injured fibre and which nearly always harbour resting pink bollworms.

During observations on these parasites both in captivity and in the field on a single occasion only was a female seen to pierce the shell of a damaged boll, and in this case the spot where the ovipositor was inserted was rotten and soft. They always appear to work on the exposed locks of mabrum cotton. In the case of « double seeds » also, no attempt was made to pierce the seed-coat in order to reach the pink bollworm, but the ovipositor had to be inserted through the silk joining the two seeds together.

If the *Pimpla* is unable to pierce with her ovipositor the shell of an unripe green boll, the utility of the parasites will be considerably handicapped, since they will not be able to commence their useful work until late in the season when there will be a sufficient supply of damaged ripe bolls containing pink bollworms, and thus the period for their increase will be comparatively short*.

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* Since this was written I have been able to observe the behaviour of *Pimpla roborator* when in captivity towards unripe green bolls infested with the pink bollworm. The females do not often appear to attempt to pierce the solid undamaged shell, or if they do so their efforts do not seem to meet with success : but they will carefully examine a green boll and an exit hole or other wound which has been made by either of the bollworms; or any other defect in the shell, however small, at once attracts their attention. At such spots they will thrust in the ovipositor to its full length in the endeavour to locate a pink bollworm in order to sting and oviposit upon it. No doubt a crack in a boll caused by proliferation, or to natural ripening, also permits the female to explore the interior of such bolls with her ovipositor.

A female has been seen to try and enlarge with her jaws a small wound in the shell,

SEASONAL HISTORY OF *PIMPLA ROBORATOR.*

There is little to be said on this subject, since at the present time little or nothing is known about it. We know that this parasite occurs both in the cultivated land and in the desert wadys in the late summer and autumn months and also during the winter and early spring — February and March. But what it does during the summer (June, July, and August) has yet to be ascertained.

In the laboratory we have had individuals emerging in March from bolls picked in November which shows that during the winter the life-cycle may be considerably prolonged.

A record which if it could have been confirmed would have been of great importance was obtained from the 50,000 bolls kept in the large breeding cage (see page 151). On the 20th of July a *Pimpla roborator* is recorded as having escaped from the cage when the door of the «trap» was opened (at this time live moths were being secured). Mr. Andres made this record and he saw the insect sufficiently well to be fairly certain that it was a *Pimpla roborator*. However, at the best, this record can only be put down as a doubtful one. If, however, the insect was of this species, then it would tend to show that *P. roborator* may pass through a period of æstivation, this would be a great advantage to the species. Some weight is lent to this possibility by the tendency of certain of the larvæ kept under observation to spend a much longer period than the

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made in the first place in all probability by one or other of the bollworms, in order the more easily to insert and get better play for the ovipositor.

To what extent the females of this species work on infested green bolls in the field has yet to be learnt, but I do not think it will be a common habit.

It is now known also that a female can with some difficulty pierce the shell of a dry boll if it is not too dry and tough. The ovipositor is often, though not invariably, inserted through the bottom of one of the numerous pits studding the shell of the boll. A clean hole, or a number of holes all close together, is drilled through the shell. The attempt to pierce the shell of a dry boll does not seem to be made at all often.

normal in the pre-pupal stage; and furthermore, one larva lived for two months but gradually shrank until it was only a half or less of the normal size when it died without pupating.

Since *Pimpla roborator* has increased during the past three years we must infer that in some way it is able to maintain in the following year the advantage of a great increase gained in the previous autumn, consequent on an abundant supply of hosts in the form of the pink bollworm. How does it do this? That it is able to do so would seem evident, since unless this Pimpla is a very longlived insect, or it has the power of æstivating, it must find during the winter, spring, and early summer an increased host population on which to maintain its own increased numbers; otherwise the species would, one would think, tend to return to its normal status, losing, or at all events losing to a very large extent, the advantage obtained in the previous autumn. Possibly the numbers of pink bollworms available as hosts are rather larger in the fields at this time than we think; possibly also, the female Pimplas work on the bolls left on the plants which have been made into heaps in the fields or stored away on the roofs of houses. Again, the question of alternative hosts here becomes of great importance, but unfortunately we know nothing about this question in Egypt. In Europe and other countries however, *Pimpla roborator* is known to be parasitic on a number of insects belonging to quite different natural orders. In Egypt it is also certain that it has other hosts besides the pink bollworm but as to the number or range of these we are again ignorant.

PREDACEOUS HABITS OF THE FEMALE.

On several occasions both in the observation cages and in the field, females of this species have been seen to deliberately eat their way through to a pink bollworm, lying in a cocoon which was within easy reach of the surface of a dead lock of cotton in a damaged boll, in order to feed upon it. From one half to practically the whole of a larva thus attacked may be devoured. Whether or not the larva is generally stung preparatory to its being fed upon has not yet been ascertained, but at all events it is

not so in all cases, since in one instance when a female was disturbed at one of these repasts the victim, although much mutilated, still showed signs of life. As the larva is eaten it is generally pulled further and further out of its cocoon.

This predaceous habit can hardly be looked upon as advantageous or beneficial, since it tends to lower the number of the offspring which might be secured from the available hosts, owing to the wasteful destruction of some of them to satisfy what is perhaps the perverted taste for flesh on the part of certain of the females, although it may be more general than we think. Furthermore, it appears that this habit may be carried a step further and develop into a most decidedly bad one, since a female has been convicted on one occasion of biting through the cocoon and devouring the remains of a pink bollworm which was already serving — or rather had served — as the host of a partially grown *Pimpla* larva — for in this case as it so happened the parasitic larva was dead. But there is no reason to suppose that the same thing might not have occurred if the latter had been alive, and being deprived of its host it would have most probably perished of starvation, even if the female *Pimpla* had not per chance after devouring the pink bollworm turned cannibal and made a meal of an immature member of her own race.

SUPERPARASITISM AND SELF-PARASITISM.

Superparasitism. — Superparasitism has been observed to occur frequently in the case of *Pimpla roborator* under certain conditions.

The term Superparasitism was proposed and has been lucidly defined by Mr. W. O. Fiske[51] as follows :—

« Superparasitism results when any individual host is attacked by two or more species of primary parasites, or by one species more than once. It differs materially from secondary parasitism, or hyperparasitism as it is variously called, although both are, strictly speaking, double parasitism of an individual. In superparasitism the parent females are both attracted to primary host primarily for its own sake. In hyperparasitism one of them is attracted to the primary host secondarily and incidentally and for the sake of the primary parasite which it harbours. »

Under certain conditions the females of *P. roborator* appear to lack to a marked degree the necessary prescience to enable them to determine whether their host — the pink bollworm — is in a suitable state to permite of oviposition by them, since one of these larvæ may be stung and oviposited upon from twice to as many as eight times by the same or several females. This faulty instinct on their part can only result in a very great waste of eggs and consequent loss of control efficiency, one pink bollworm being sufficient only to bring to maturity one healthy *Pimpla roborator*.

What takes place exactly in such a case as the above when more than one egg is laid on a pink bollworm has not yet been ascertained, but the following would, judging by the work of Fiske [52], seem to be the possibilities :—

1. One *Pimpla* larva might gain sufficient start and become sufficiently large and strong to prey upon and destroy the other larva or larvæ which subsequently hatched from the remaining egg or eggs. In this case the result would be that only one *Pimpla* would reach maturity out of two, eight, or perhaps more eggs; and moreover, only one pink bollworm would have been destroyed instead of many.

Some evidence has been obtained in the case of *P. roborator* supporting the above supposition.

2. It would seem possible, although probably rare so far as observations made on *P. roborator* tell us, that two stunted individuals of this species having inferior reproductive capacity might be raised from the same host pink bollworm*.

3. That none of the *Pimpla* larvæ will reach maturity owing to

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* A propos of this question it is of interest to note that very small individuals of this species may be reared from damaged cotton bolls. In November of this year (1915) males measuring only 6 mm. to 8 mm. in wing expanse and 5 mm. to 6 mm. in length of body were obtained. Females of 10 mm. wing expanse and 10 mm. in length of body (including the ovipositor) were also noted.

starvation brought about by an insufficient supply of food consequent on the excessive parasitism of a single host. A very probable result.

Self-parasitism. — Unfortunately the list of the bad habits of *P. roborator* does not end at superparasitism, since it has been further convicted of what, for want of a better term, I can only describe as *Self-parasitism.* The females will sting and oviposit on their own larvæ of any size whilst the latter are feeding on their host, the pink bollworm. The *Pimpla* pupæ are also destroyed in a like manner. *Pimpla roborator* larvæ have been raised to the adult stage with a larva of the same species serving as the host.

The writer was puzzled for some time at finding mature larvæ of this species brownish in colour soft and apparently dead in the cocoons of resting pink bollworms, until the true cause of their decease was ascertained — namely, that they had been as it were assassinated by the females of their own kind.

THE IMPORTANCE OF SUPERPARASITISM AND SELF-PARASITISM AS A CHECK ON THE EFFICIENCY OF *PIMPLA ROBORATOR* AS A NATURAL ENEMY OF THE PINK BOLLWORM.

Until recently, this parasite was looked upon as at least showing some promise of developing into a decidedly useful check on the increase of the pink bollworm. However, now that we know more about its habits, there are good reasons for fearing that expectations in this direction may not after all be realized.

It has been pointed out already that there is a possibility of the useful work of this parasite being handicapped owing to the feared inability of the females to attack the pink bollworms in the green bolls. Then again there is the tendency of the females towards ill-judged carnivorous habits; these, however, may be of but minor importance as a check on its own increase. But now, and of very much greater importance, there are the adverse effects of superparasitism and self-parasitism to be taken into

consideration. It is, however, at present very difficult, if not impossible to apprise the true value of these bad habits and the checking effect they will have on the increase of *P. roborator,* since we require to know if the lack of prescience on the part of the parent females is equally apparent when their hosts are much more numerous in proportion to themselves than was the case in the laboratory garden in February and March, when the observations were made. In this instance a comparatively large number of females were crowded on a small number of hosts concentrated in a very limited area. Such conditions could but tend to increase the tendency towards superparasitism and self-parasitism evidently possessed by this species. Under normal field conditions in the summer and autumn the chance of either of these phases of parasitism taking place would be more remote. On the other hand, one must admit that as soon as *P. roborator* becomes at all numerous in the field the bad habits of the females are likely to be manifested to the same extent that they were in the case quoted above and the probable result will be that the species will be so reduced by its own excesses that the pink bollworm will be able to again increase unhindered by its attacks.

In the case of the bolls in the laboratory garden it is believed that hardly any adult *Pimplas* emerged from them owing to the adverse effects of the prevalence of superparasitism and self-parasitism.

THE EFFECT OF AUTUMN BOLL DESTRUCTION ON *PIMPLA ROBORATOR.*

The destruction in the autumn of all the bolls which have been injured by and which are infested with the pink bollworm, although an essential step for the control of this pest, must nevertheless be in many cases, I think, a serious disadvantage to the welfare of *Pimpla roborator;* because the destruction of these bolls means the destruction of large numbers of Pimplas also, and so the increase of a useful insect is unavoidably checked.

It is during the autumn months that this parasite increases, and it is

not until the latter part of November that it seems to become really numerous. Thus the destruction of bolls at this season must of necessity result also in the death of great numbers of the immature stages — eggs, larvæ, and pupæ — of the Pimpla. As an example of this the following experience is of interest.

On our farm at Bahtim in 1915, an area of five feddans of cotton was grown. The last examination of green unripe bolls was made on September 15th, 900 bolls from 200 plants being carefully examined in the laboratory; but no sign of the Pimpla was found in a single one of these bolls. Had a similar number of the dry and open damaged bolls been looked at the probability is that the parasite in one or more of its stages would have been found, but not in any great numbers I fancy, judging by a preliminary examination of these bolls.

The probabilities are then, I believe, that this insect is not very numerous by the middle of September, nor does it appear to attack the pink bollworms in the unripe or green bolls.

About the 7th of November the cotton plants were pulled up and burnt. But before this took place all the bolls from the plants on one feddan out of the five were picked off and brought to the laboratory.

From these bolls *P. roborator* emerged as follows :—

	MALES.	FEMALES.	TOTAL.
November 8th to 14th	83	39	122
— 14th to 16th	70	50	120
— 16th to 19th	116	78	194
— 19th to 22nd	234	124	358
— 22nd to 23rd	115	63	178
— 23rd to 25th	244	155	399
— 25th to 27th	325	204	529
— 27th to 29th	291	240	531
— 29th to 1st	57	91	148
December 1st to 4th	39	61	100
— 4th to 6th	5	20	25
— 6th to 7th	0	5	5
— 7th to 9th	1	3	4
— 9th to 13th	0	0	0
	1580	1133	2713

These figures show that in November the Pimpla is very common, and from them it will be readily understood also how great must be the mortality which may occur in a large number of cases and the consequent set back the species must receive from the destruction of the bolls at this season.

By this I do not of course mean to suggest that boll destruction should be stopped in order to help this parasite, but the question of the relation between this measure and the Pimpla has been raised as an example of how difficult it often is to reconcile the artificial control of a pest as carried out by man, with the control or partial control that may be effected by a natural agency such as a parasitic insect or insects — for the disadvantage of boll destruction must apply to the several parasites of the pink bollworm and not to the Pimpla only. This drawback however, cannot be evaded and really it is of little significance if the artificial control practiced is sound in conception and effectually carried out, since from a practical point of view an effective control or destruction of the host insect must equally effect its parasites where a pest like the pink bollworm is concerned and under the conditions which prevail in Egypt.

Left to itself the increase of *Pimpla roborator* should, up to a certain point and supposing it has alternative hosts, be progressive; but the autumn destruction of the bolls will — if carried out thoroughly — prevent this. However, one thing is, I think, very certain; namely, that the destruction of all bolls left on the plants after the last picking of lint has been taken, will be (combined with other necessary steps, and always assuming that it is done thoroughly) a very much more effectual and sure way of controlling the pink bollworm than relying on *Pimpla roborator* to deal with it.

On the other hand, the later (within reason) the bolls are removed from the plants the greater — up to a point — will be the active Pimpla population at the end of the season, and, what is of greater importance still, owing to the work of these parasites in a cotton field the smaller will be the number of live pink bollworms left in the dead bolls which are knocked of the plants when the latter are pulled up, and consequently the less will be the danger from these bolls being ploughed in and

forming a safe haven for the resting pink bollworm to pass over to the following July-September period and then give rise to moths which will invade the new crop. That the bolls infested with resting pink bollworms which are buried in the soil by the ploughing or fassing of the land for a crop following cotton, may be a danger to the next cotton crop has already been explained — *vide* pages 155-175.

NATURAL ENEMIES OF *PIMPLA ROBORATOR.*

So far the only natural enemy of this species that has been observed is the mite *Pediculoides ventricosus*, which attacks the *Pimpla* when in the cocoons of the resting pink bollworms in cotton seed.

PTEROMALID PARASITES OF THE PINK BOLLWORM.

The two following insects have not yet been identified; even as regards their generic position with certainty. Both appear to undoubtedly belong to that large tribe of the family Chalcididæ — the Pteromalini. The Large Pteromalid would seem to be a member of the genus *Pteromalus*. As regards the other species, which for the moment I have written of under the title of «The Small Pteromalid», although it does not perhaps belong to *Pteromalus* it at least comes near to that genus and has the same habits.

It is hoped, that notwithstanding the lack of the scientific names of these two interesting little parasites, the descriptions, the coloured drawings and enlarged drawings of the wings and antennæ, will enable other observers to recognise the two species dealt with in the following notes.

THE SMALL PTEROMALID.

This little Chalcid (Plate VI, Figs. 4-5) was observed for the first time in February 1915, in a breeding cage in which were a number of *Pimpla roborator* females and cotton seeds infested with pink bollworm. A single

female was seen creeping about amongst these seeds. At first it was thought that a distinct relation existed between this *Pteromalid* and *P. roborator*, since the female appeared to attempt oviposition only in those seeds in which a *Pimpla* had first been seen to oviposit or attempt to do so. Further work, however, has shown that this idea was erroneous and it has now been ascertained beyond doubt that this Chalcid is, or at any rate under certain circumstances may be, a primary parasite of the pink bollworm.

As in the case of *Pimpla roborator* so with this parasite, the females do not seem to be able to determine in all cases whether a cotton seed harbours a host in a suitable condition for oviposition until the interior has been explored with the ovipositor. A female may be seen in what is apparently the act of stinging or oviposition upon a pink bollworm in a double seed, yet on opening the latter it may be found to be quite empty or to contain a pink bollworm that has already been killed by mites or disease. However, eggs have not been found as yet on dead larvæ which had been killed by some other agent.

Where the single female first captured came from I do not know; but in April several males and females of this species were found in a seed capsule of hemp or teel (*H. cannabinus*) received from Shebin-el-Kom in February 1915. Probably the first female came from one of the numerous samples of teel or from cotton seed then in the laboratory.

Recently specimens of this Pteromalid have been brought to me by Mr. Gerboa, found in cotton seed in Mr. Victor Mosseri's laboratory; so perhaps this parasite is more common than we think.

LIFE-HISTORY AND HABITS.

The stinging of the host. — The female *Pteromalid* has first to render the pink bollworm insensible before she can proceed with oviposition. This act is accomplished by stinging it through the silken wall of the cocoon by means of her combined sting and ovipositor. Both during the act of stinging the host and egg-laying the female remains almost motionless

except for an occasional movement of the antennæ and a thrust of the ovipositor; the abdomen assumes a very characteristic triangular form, the apex pointing downwards and ending in the ovipositor.

A pink bollworm when it is being attacked often exhibits very great fear of the parasite, turning and twisting about in its cocoon to avoid being stung; it will even bite its way out of the cocoon and so escapes. When the cocoon is formed amongst lint cotton or some similar material the bollworm may be seen attempting to bite the *Pteromalid* through the cocoon and sometimes it seems to meet with success and the aggressor is seized and killed.

Pink bollworms which have been stung may exhibit numbers of small black specks and lines on the skin. In some cases the body turns entirely dark brown in colour.

THE ADULT.

The female (Plate VI, Fig. 4) :— Length about 2.5 mm., wing expanse 5 mm. Colour, to the naked eye the insect is polished black with

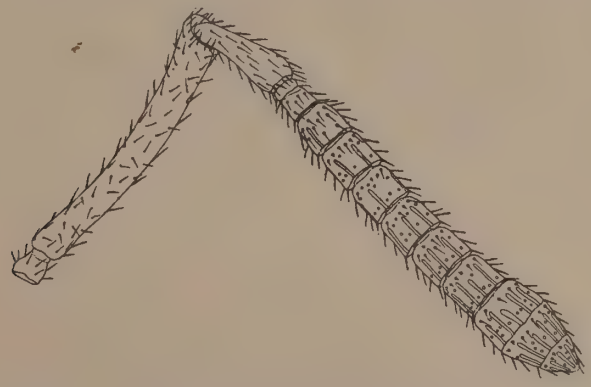

Fig. 10. — Antenna of small Pteromalid. Greatly enlarged.

silvery wings, but really the colour is dark bronze-green; after death the colour tends to become more of a dark steely blue.

Head wider than thorax. Colour, dark bronze-green, punctuate. Face slightly depressed along the median longitudinal line. The antennæ (Fig. 10) are inserted in the head at a point about level with the lower

margin of the eyes. Scape yellowish-brown to pale ferrugineous; flagellum dark, clothed with fine silvery hairs. Eyes naked, dark brown in colour, ocelli dark. The mouth is provided with a powerful pair of mandibles, both the right and the left mandible have four teeth. Thorax dark bronze-green, punctuate. Legs yellowish to pale yellowish-brown, femora darker; tarsi five jointed, yellowish or yellowish-brown with the last joint and claws dark. Wings (Fig. 11) transparent, iridescent; radial nervure about equal to the costal nervure. Abdomen pointed, very dark bronze-almost black, polished. The dorsum of the abdomen is not depressed in life but after death it falls in.

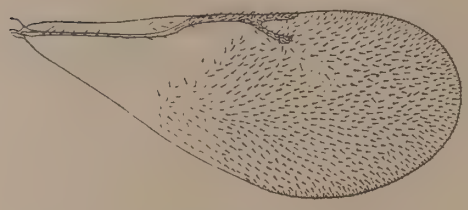

Fig. 11. — Wing of the small Pteromalid. Greatly enlarged.

The male (Plate VI, Fig. 5) :— The male is smaller and more active than the female. The colour of the head and thorax is bronze-green, punctuate. The antennæ are yellowish-brown — both the scape and the flagellum. The legs are yellowish, paler than in the female. Abdomen rounded at the apex, dark except at the base, where it is yellowish-brown giving rise to a pale spot which forms a conspicuous feature of this sex and alone makes the identification of the male a very easy matter.

THE EGG.

The egg (Plate VI, Fig. 6) is very small, measuring only 0.34 mm. in length and 0.1 mm. in diameter at the broadest end. In form the egg is somewhat comma-shaped, round in section and slightly curved on one side. At first the colour is opaque or greyish-white, but later they become almost colourless and glassy. The shell is covered with minute projections or papillæ.

The number of eggs laid on a larva varies from about twelve to as

many as twenty-six, but this latter number is probably abnormal, since a single pink bollworm is not sufficient to properly nourish so many larvæ, the resulting adults being very small indeed with poor reproductive powers. In breeding this Pteromalid in captivity it is important to provide an abundant supply of hosts, otherwise the tendency is for the parasites to lay too many eggs on one host, or to sting the latter so many times that they appear to be killed outright with the result that the larvæ will not develop on them.

The eggs are laid in a heap, or singly here and there on the pink bollworm, or perhaps between it and the side of the cocoon. They are not attached to the skin of the host.

The egg stage lasts from 2 to 3 days in summer.

THE LARVA.

The larva is at first colourless and glassy in appearance owing to its very shiny skin. They have a well developed head, but are devoid of legs. As they absorb the contents of their host they become yellow, pinkish, or brown in colour. They feed with the mouth pressed closely against the skin of the host, which may become discoloured to a brown hue at the site of the feeding puncture. When the parasite is feeding a constant succession of internal peristaltic-like wave movements may be seen proceeding from the head to the tail end of the body.

The larvæ may feed dispersed over the body of the host or together in a mass, one being curled over the other (Plate VI, Fig. 9). When full grown the larva (Plate VI, Fig. 7) is about 2.5 mm. to 3 mm. long and brownish in colour. At this stage the dorsal surface may be mottled with rounded indistinct opaque spots. The larvæ remain in the cocoon of their host which will now have been reduced to an empty skin and the head. In about 24 hours they become white and will have voided or will shortly void a small quantity of black excrement. After a further brief interval the larval skin is shed and the pupa disclosed.

The larval stage lasts about 5 to 7 days.

THE PUPA.

The pupa (Plate VI, Fig. 8) is at first pale, but later becomes yellow or buff in colour. The head, antennæ, legs, wings, etc. of the future insect are visible.

The pupal stage lasts about 7 days and then the adult Chalcid emerges, the pupal skin being shed as a small yellow pellicle.

PROPORTION OF THE SEXES.

The number of males and females coming from a batch of eggs laid on a host may be very disproportionate, as was the case in the following examples :—

	FEMALES.	MALES.	
From eggs on host N° 1	9	3	were reared.
— — — 2	11	0	—
— — — 3	11	1	—
— — — 4	8	3	—
— — — 5	14	4	—
— — — 6	18	3	—
— — — 7	9	0	—
— — — 8, 9, 10	39	9	—
	119	23	

OCCURRENCE OF PARTHENOGENESIS.

This *Pteromalid*, like many of its kind, is parthenogenetic; that is to say the female can lay fertile eggs without having been impregnated by the male. The offspring, however, in such cases are all males; but as it is quite possible for a female to live long enough to see her own offspring, she would stand a chance of being fertilized by one of these and so might be able to give rise to eggs of both sexes before her death.

The following table shows the offspring from eggs laid on pink bollworms by virgin females :—

Table L.

PARTHENOGENETIC REPRODUCTION.

NUMBER OF HOST.	NUMBER OF EGGS LAID ON HOST.	NUMBER OF FEMALES REARED.	NUMBER OF MALES REARED.
1	26	0	26
2	17	0	17
3	17	0	17
4	9	0	9
5	12	0	12
6	2	0	2
7	13	0	13
8	22	0	22
9	6	0	6
10	19	0	19
11	16	0	16
11	159	0	159

COURTSHIP OF THE SEXES. — The males follow the females about with great activity and pay much attention to them. They have the curious habit of standing on the head and thorax of the female and stroking her head and eyes with a very deliberate downward and backward movement of the antennæ. In this position they may be carried about by the females. The act of coition appears brief and in some cases it seems possible that it may take place within the cocoon of the host before the emergence of the insects.

THE LARGE PTEROMALID.

This Chalcid, which appears to belong to the genus *Pteromalus,* was first obtained (two or three specimens only) in the autumn of 1913 from cotton bolls collected at Bahtim, near Cairo. In 1914 it was found again, but only in small numbers. This year (1915) it has been rather more common from the same locality. It has now been established that the pink bollworm may serve as one of the hosts of this Pteromalid, but whether

this species is really its normal host or the only one has yet to be ascertained, for in addition to *Gelechia gossypiella* there were present also, the larvæ of *Earias* and of *Pyroderces*.

The females of this large Pteromalid when in captivity and provided with pink bollworms spun up in cotton fibre or in fine muslin will readily attack and render the larvæ insensible by stinging them a number of times by means of the ovipositor. Whether they oviposit on these stung larvæ so readily is not yet clear; that they do so is of course certain as the insect has been reared through from egg to adult on this host.

DESCRIPTION AND LIFE HISTORY.

The female (Fig. 12):— Length 3 mm., wing expanse 7 mm. General colouring metallic bronze-green or metallic coppery bronze with strong coppery reflections.

Fig. 12. — The large Pteromalid. Greatly enlarged.

Head wider than thorax. Face depressed in middle, punctuate. Anten-

Fig. 13. — Antenna of large Pteromalid. Greatly enlarged.

næ (Fig. 13) inserted in face at a point just above the level of the lower margin of the eyes : scape yellowish-brown to ferrugineous; flagellum

dark, clothed with fine silvery hairs. Eyes naked, reddish or reddish-brown; ocelli black. Mouth provided with a pair of stout mandibles. The right mandible is 4-toothed; the 4th or upper tooth being chisel-shaped, the others bluntly pointed. The left mandible has three teeth only; 3rd or upper tooth chisel-shaped the other two bluntly pointed.

Thorax metallic bronze-green or coppery-bronze deeply punctuate, punctuations giving rise to a raised reticulate sculpturing or ornamentation (Fig. 14). Wings (Fig. 15) do not reach quite to the end of the abdomen, transparent and iridescent; the costal nervure decidedly longer than the radial nervure. Legs, coxæ and femora same colour as the body, but tips of femora pale. Tibiæ and tarsi of first pair of legs pale yellowish-brown, the last joint of the five jointed tarsus and the claws are dark. The apex of the first tibia is armed with a long hairy spur bifid at the apex,

Fig. 14. — Sculpturing on thorax of the large Pteromalid.

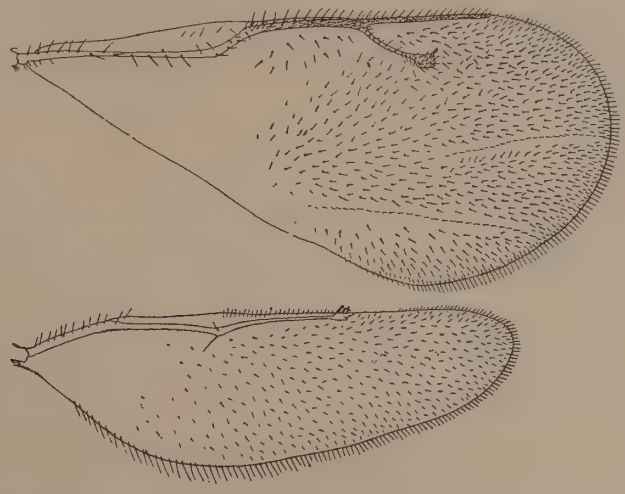

Fig. 15. — Wings of the large Pteromalid. Greatly enlarged.

and on each side of the spur a series of five stout spines : the first tarsal joint is furnished with a conspicuous comb-like arrangement of tooth-like spines. The second and third tibiæ and tarsi are pale, but the last joint of the five jointed tarsi and the claws are dark. The tibia of the second pair of legs is armed with a hairy spur not bifid at the tip and a series of

stout spines on each side; the spur on the third tibiæ is simple and not hairy.

The abdomen is the same colour as the thorax, smooth and polished, sparsely clothed with longish fine silvery hairs especially towards the apex, which is pointed.

The male :— Length 2.5 mm. Wing expanse 4 mm.

The male is smaller and more active than the female but in colour it is very similar, perhaps a little brighter, and the abdomen besides being much more rounded at the apex, has towards the base a conspicuous pale brownish spot.

THE EGG.

The eggs are laid on the body of the host but are not attached to the skin. The egg is comma shaped when viewed from the side and measures about 0.47 mm. long by 0.14 mm. at the broad end tapering to 0.06 mm. at the narrow end. In colour it is translucent white or yellowish-white. The surface of the egg is thickly studded with minute papillæ or projections.

THE LARVA.

When first hatched the young larva is a tiny, clear, glassy-looking arched creature, tapering towards the posterior part of the body, and provided with a well-marked rounded head furnished with a pair of short spine-like antennæ, and a mouth armed with a pair of small chitenous mandibles. The segmentation of the body is clearly defined. As the contents of the host are absorbed the larva may become yellowish, but the ends of the body remain clear. The young larva possesses ambulatory powers and can and does move about on the body of its host, feeding at different places. The site where the larva has fed is marked by a round spot, or a ring with a spot in the middle, or a series of shaded rings of a brown colour. I believe that during its feeding period the larva excretes a small quantity of a clear fluid, but no solid ecreta is passed until the larva has left the host and is preparing to pupate.

The full-grown larva is about 3 mm. long and of a dark purplish-brown hue with clear ends; the colour is due to the contents of the alimentary tract showing through the shiny transparent skin. Viewed from the side, both the dorsal and ventral aspects of the body are distinctly and broadly corrugated transversely, the corrugations corresponding to the segmentation; they give one the impression of being something in the nature of pseudopodia to assist in locomotion. The body bears a few stout hairs or processes, especially on the dorsal and ventral margin of the last segment, but their number and exact arrangement can not be easily seen on the living larva.

During the pre-pupal quiescent period the larva voids a small quantity of black excretory matter in the form of a fused mass of tiny rounded pellets; after this the larva is of a yellowish-white colour and not transparent.

THE PUPA.

The pupa is of typical Chalcedoid form, yellow in colour.

The duration of the life-cycle has not yet been worked out in detail, but when the different stages are kept in an incubator at about 32° C the period is short.

THE PINK BOLLWORM CHELONELLA.

Chelonella sulcata, Nees.

This pretty little Braconid — *Chelonella sulcata,* Nees.,* has been bred in some numbers from bolls infested with the pink bollworm on which it is thought to be parasitic.

So far little or nothing is known of the habits of this parasite; but it is believed to live as a larva within the body of the pink bollworm until the latter transforms into the pupa stage. The *Chelonella* larva then completes its growth, feeding on the contents of the pupa, which is thus destroyed.

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* I am indebted to Dr. Gough, entomologist to the Ministry of Agriculture, for the identification of this insect.

The parasite then pupates inside the empty *Gelechia* pupa and later the adult emerges.

The ovipositor of *C. sulcata* being quite short, it seems unlikely that it can attack a pink bollworm when it is well inside a green boll, but it probably has to wait until the bolls have ripened and split open before it can creep in and get near enough to a larva to sting and oviposit in it. It would be able also to gain the interior of a green boll if there was an exit hole in the shell and to attack the other bollworms which might still be in the interior.

A particularly interesting point in the life-history of this insect is that it appears well-adapted to the seasonal habits of its host, since the adult insects emerge in June, July, August and September from the infested bolls of the previous year's crop. It is at this period of course that the resting *Gelechia* larvæ transform to the pupa stage. It is thus not surprising to find the *Chelonella* emerging at the same time — if we are correct in supposing that this parasite does not complete its growth until the host has assumed the pupal state.

The emergence of *C. sulcata* in 1914 from 1913 bolls is shown on Plate II by the dotted line curve.

Plate V, Fig. 12 shows the appearance of *C. sulcata*, a small black Hymenopteron measuring some 3 mm. to 4 mm. long with a wing expanse of about 6 mm. The colour is black, but there is a prominent pale yellowish area at the base of the abdomen. This pale area may be absent altogether or reduced to a small spot of a yellowish or in some individuals of a ferrugineous hue. Out of 254 specimens bred from bolls (locality Bahtim) in 1914, 177 had the yellow spot at the base of the abdomen, and 77 were of the all-black variety.

In 1914 *Chelonella* appeared to be rather less numerous in bolls received from Bahtim, near Cairo, than was the case in the previous autumn*.

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* December 13th, 1915. *C. sulcata* appears to be again less numerous this year than it was in 1914. So far, from the bollworm damaged bolls from one feddan of cotton, only about half a dozen individuals of this species have been obtained.

THE BOLLWORM BRACONID.

Rhogas kitcheneri, Dudgeon and Gough.

This Braconid (Plate VI, Fig. 13; and Plate VII, Fig. 10) has been reared in captivity on the pink bollworm, but so far I have not actually found it in the field on this host. The opportunities for Rhogas to attack the pink bollworm under natural conditions will not, I think, be very numerous. The female parasite is armed with a short ovipositor and so will not be able to reach a pink bollworm well inside a boll, from the outside; the only chance of a successful attack on this host would appear to be for the parasite to gain the interior of an infested green boll through an exit hole left by a larva that has reached maturity before other pink bollworms in the same boll; the latter in this case might be open to attack. However, I judge that this seldom happens because of the few individuals of this species which I have obtained from tens of thousands of bolls harbouring *Gelechia* larvæ. I believe that all or nearly all of the *Rhogas kitchenerii* which may be obtained from cotton bolls picked at the end of the season, and placed in breeding cages, come from the ordinary bollworm (*Earias insulana*) which from the nature of its habits is very much more open to successful attack by the *Rhogas*. The latter is of course a well known and common parasite of *E. insulana* in Egypt. A full account of the life-history and habits of this parasite has been published by the writer in the *Bulletin de la Société Entomologique d'Égypte*[53]. The species was described as *Rhogas kitcheneri* by Dudgeon and Gough[54].

In the autumn of 1914 it was noted that amongst the individuals bred from bolls infested with *Gelechia*, *Earias* and *Pyroderces* the male sex predominated. Out of 113 specimens emerging during November only six were females, the rest — 107 — being males. This is curious and would tend to show that perhaps parthenogenetic reproduction may occur under certain conditions*.

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* December 13th, 1915. Very few specimens — not more than about twenty-five — of this Rhogas have been obtained from the bolls picked from one feddan of cotton at Bahtim,

LIMNERIUM INTERRUPTUM.

This ichneumon fly, shown on Plate V, Fig. 13, has been bred during the past two seasons (1913-1914) from cotton bolls infested with pink bollworm. It is thought that it may perhaps be parasitic on the latter, the members of the genus *Limnerium* being primary parasites on the larvæ of Lepidoptera. The male is similar in colouring and appearance to the female, except that it has no ovipositor.

This insect was less numerous in 1914 than in 1913 in bolls obtained from the Society's farm at Bahtim*.

A BETHYLID — A PARASITE OF THE PINK BOLLWORM?

Fullaway[55] has recorded a Bethylid, believed to be *Parasiorola cellularis*, as a parasite of the pink bollworm in Hawaii.

During the past three years I have obtained from cotton bolls infested with *Gelechia gossypiella*, *Earias insulana*, and *Pyroderces simplex*, specimens of a bethylid, but on which of these three insects (if on any one of them) it is parasitic has yet to be determined. The bethylids were not numerous, but at the same time they were not rare.

In January of the present year a female bethylid was found in a dry bamia seed-pod. Placed in a glass tube with some pink bollworms and *Pyroderces* larvæ she almost immediately proceeded to attack them in a

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November 7th. This is significant and is due no doubt to the corresponding scarcity of *Earias insulana* of which only two or three dozen specimens (moths) were obtained. The scarcity of this pest in this case was probably due largely to the very few green bolls present on the plants during October. In a weight of 165 kilos of bolls picked from the one feddan on November 7th there were only 46 green unripe bolls! The rest were dry bolls badly injured by the pink bollworm.

* December 13th, 1915. This Limnerium does not seem to show any signs of increase this year at Bahtim — in fact it seems less numerous than it was in 1913. On the whole I feel by no means certain that this insect is parasitic on the pink bollworm, and really from its scarcity one might be led to connect it with the *Pyroderces* larvæ or even *Earias* both of which — more especially the latter — have been scarce also.

fearless and most reckless manner, seizing what may really be described as a regular bulldog hold with her powerful jaws anywhere on the body and being dragged about and rolled upon over and over again by the larva in its struggles to rid itself of the aggressor; when possible, attempts were made to sting the larva but without effect. However, this particular female was not very strong when obtained and the subsequent tussles with the *Gelechia* and *Pyroderces* larvæ may have so reduced her strength that she was incapable of inflicting a fatal sting.

These bethylids (Plate V, Fig. II) are quite small to small insects measuring about 2 mm. to 3 mm., up to 4 mm. in length. In general appearance they are somewhat ant-like, owing perhaps to their large and rectangular head and the long low poised body. The head, thorax and abdomen are black and polished, sparsely covered with short silvery hairs. The eyes are very dark brown, almost black; antennæ yellowish-brown; the mouth is provided with a pair of very powerful jaws or mandibles. The wings are silvery. The femoral joints of the first and third pair of legs are robust, especially the first pair, black or brownish in colour and covered with silvery hairs. The femora of the second or middle pair of legs are the least powerful. The tibiæ are yellowish-brown with a dark median area, tarsi yellowish with black claws.

The abdomen is pointed and is armed with a concealed sting and ovipositor, short but powerful.

It is evident that these bethylids from their very small size and short ovipositor must only be able to attack the pink bollworms, if they do so at all, when they are inside a boll and not from the outside. For this reason it will be the resting larvæ in the ripe damaged bolls which will be most susceptible to attack one would think; but they could also perhaps crawl into green bolls through exit holes and so reach the other larvæ in the interior*.

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* December 13th, 1915. Quite a number of this bethylid have been obtained again this autumn from cotton bolls damaged by bollworm and infested with *Gelechia*, *Earias* and *Pyroderces* larvæ, the last two being much in the minority. However, these little parasitic

ARTIFICIAL METHODS FOR THE CONTROL OF THE PINK BOLLWORM.

The methods that may be adopted for the control of the pink bollworm resolve themselves into two divisions; the first and by far the most important being *Preventive Measures*, that is to say, the employment of some method or methods which will ward off or greatly reduce the severity of the attack the following season. Secondly, there are the *Direct Measures* of fighting the pest in one or more of its stages when it has already made its appearance in the field and commenced its destructive work on the cotton.

PREVENTIVE MEASURES.

The old adage «prevention is better than cure» is always a good maxim to follow when dealing with insect pests, and in the present case it seems especially suitable, since in the present state of our knowledge, prevention — realisable largely by the employment of simple cultural

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wasps do not seem to have increased in any marked manner since 1914 — that is to say as regards the locality of Bahtim.

It has now been ascertained that they will — in captivity — readily attack pink bollworms and that they can sting and paralize them. They also bite through the skin of the bollworm with their jaws and feed on the body juices.

Although the bethylids readily attack the pink bollworms they seldom seem to lay eggs on them and I have only succeeded in obtaining three or four eggs, but only one of these was reared successfully to the adult stage. This single success, however, has shown that the pink bollworm *may* form a host for this bethylid.

The eggs were translucent whitish bodies about 0.44 mm. long by 0.16 mm. in diameter, rather broader at one end than the other; slightly curved on one side and cylindrical in transverse section. The eggs are laid externally. The larva, which fed externally on its host, was when full grown about 3 mm. long and rather bladder-like, but tapered considerably towards the head. The segmentation is inconspicuous and the skin smooth and very shiny. In colour the mature larva was a clear but pale honey-yellow — almost colourless and translucent at the head and tail end of the body.

After the larva had ceased to feed and left the host some change in colouring took place.

methods — appears to be almost the beginning and end of the pink bollworm problem in Egypt.

Before going further, it is essential to recall the fact that so far the pink bollworm has been found to feed on three plants only in this country, viz. :— cotton, bamia and teel : there is also the hollyhock, but few of these plants are grown, so that their presence or absence will not make any very big difference.

Thus, assuming that none of these plants are permitted to exist during the winter and spring it would seem that the pest will be able to bridge the gap between one cotton crop and the next in one way only — namely, by the resting larvæ which pass this period in the dry damaged bolls left on the cotton sticks, and probably also in fallen bolls in the ground; in the tagawi cotton seed and perhaps to some extent in ginneries and cotton stores.

It becomes very evident then that the aim of any preventive measures must be :— firstly, to destroy all possible source of food in which *Gelechia* might continue to breed during the winter and spring until the cotton is in a condition to be attacked : and secondly, to destroy as completely as is practicable the resting larvæ in the situations in which they are known to occur.

The honey-coloured area of the body became of a darker shade and it contracted; also there became visible on it irregularly shaped white spots. Two darkish spots were visible just behind the head. The larva next voided a small quantity of dark viscous excrement. It then became of a pale opaque yellowish colour and gradually assumed the form of the pupa, the eyes of the latter being visible through the larval skin.

On about the 7th day after it had ceased to feed the larva shed its skin and assumed the true pupa stage. The pupa measure some 2.75 mm. in length and was pale yellow in colour with reddish eyes and ocelli. The legs and antennæ were plainly visible and glassy in appearance. The pupa before it changes to the adult insect gradually turns black but the antennæ and legs retain their glassy appearance until shortly before the pupal skin is shed and the perfect insect appears.

It is possible, I think, that this bethylid passes the winter in the adult stage as those at present in captivity appear to show a tendency to be long lived and inactive at the time of writing — December 13th, 1915.

Theoretically, if this is done completely it should result in the effective control of the pink bollworm, and perhaps almost complete control would be attained; because the extent to which the attack is caused by and carried on in the succeeding season by moths arising solely from those resting larvæ that have survived in the bolls which have fallen to the ground and been ploughed or fassed (hoed) in is still somewhat problematical.

In practice however, it will be found that it is almost impossible to carry out these preventive measures absolutely to the letter or in so far reaching a manner as to effect the resting larvæ in all possible situations, and so the chances are that the pest will always or at all events in most years cause some loss. But this damage will most probably more often than not pass almost unnoticed by the majority of people just as now do the annual attacks of the ordinary bollworm, *Earias insulana*, with the exception of occasional « bad » years. Such years would be likely to occur also in the case of the pink bollworm.

Although placed after the destruction of food plants, the destruction at the end of the season of the enormous number of bolls remaining on the plants, and which are likely to be heavily infested with the resting stage of the pink bollworm, is of course of premier importance. That this is an absolutely *essential* step in the control of this pest has already been pointed out and demonstrated in previous pages of this report, and no more striking proof is needed to show that this measure is the keystone to the whole structure of any campaign against the pink bollworm based on prevention, then the curve on Plate II showing the hosts of the moths that may emerge over a period of almost two years during June, July, August and September from the bolls of the previous crop. However, for the full benefits to be derived from this system, it will be necessary to support it on the one hand by effective control of the winter food plants of the pest and secondly by the destruction of the resting larvæ in cotton seed and other places.

At first it was thought that the question of seed control was of quite secondary importance to boll destruction owing largely to the fact that at the beginning the seed used for sowing the new crop was only slightly

infested and, moreover, nothing was known as to the possibility of the pink bollworms making their way to the surface to pupate and then successfully giving rise to moths. At the same time, however, it was realized that so long as danger of reinfection from this source was even suspected only, the second preventive measure became the counterpart of the first. The increasing degree to which the tagawi seed became infested subsequent to 1912 brought this question into much greater prominence, but at the same time a doubt grew up in my mind as to whether the importance attacked to it was fully justified for the reasons already discussed under «The Fate of the Pink Bollworm in the Tagawi Seed», *vide* pages 175-202.

Now, however, as there can be no doubt that infested tagawi seed may be a danger — although the extent of danger is not yet known — constituting as it does a source from which the new crop may be attacked, it appears much better to be on the safe side and be prepared to bring about the destruction of the pest in all seed intended for sowing purposes; because, like boll destruction, it is useless for one grower to use clean tagawi if one or several neighbours whose land surrounds his own continue to sow thousands of pink bollworms in their cotton seed.

Furthermore, there is the important question of the remainders of stocks (no matter how small) of tagawi seed — left over on the hands of both merchants and growers after the crop has been sown — remaining widely distributed in the Provinces until May or later still, and thus being dangerous as sources of infection for the new cotton crop. In addition there will be also large bulks of cotton seed intended for crushing, and destined for export or consumption by local oil mills.

The extent of the danger from this source can be ascertained only after careful enquiry has been made as to the amount of seed left in the interior on various dates and the methods of storing and disposing of it. But in any case it will be as well to be reconciled to the fact that in order to counter any risk to the new crop from this origin it may be necessary to treat *all* cotton seed by fumigation or heat.

The fact that seed control to be of any value must be carried out by

everyone, at once puts the measure on the same footing as the boll destruction — that is to say, it must be made compulsory; since it is evident that in a country like Egypt, or for that matter any country, it is quite useless to rely on the individual grower treating his seed before sowing, even supposing some very simple and certain way was found for effecting the destruction of the resting larvæ in the seed. It is equally apparent also, that under such conditions it would be impossible to control or enforce the measure and thus the only solution of the problem seems to be to have the necessary treatment carried out in all the ginning factories in the country as the seed leaves the gins. This being so, it will simplify matters to have every ardeb of seed fumigated or otherwise treated and thereby abolish *in toto* all danger of it acting as a source of infection to the new crop.

WINTER DESTRUCTION OF FOOD PLANTS.

The prevention of the growth of the pink bollworm's food plants — cotton, bamia, and teel — during the winter and spring should not be difficult and is provided for in the Bollworm Decree (Loi n° 19 de 1912, portant les mesures à prendre pour la destruction du Ver de la Capsule du coton) which says relative to this subject :—

Art. 1er. — Chaque année, avant le 15 décembre dans les Moudiriehs de Béni-Souef, Fayoum, Minieh, Assiout, Guirgueh, Kéneh et Assouan, et avant le 31 décembre dans les Moudiriehs de Guizeh, Galioubieh, Charkieh, Gharbieh, Dakahlieh, Menoufieh et Béhéra, les racines des plants de coton, de chanvre (Til) et de Bamieh devront être arrachées ou coupées au-dessus du niveau du sol, de manière qu'elles ne puissent donner naissance à une nouvelle pousse.

Sont exceptés les districts suivants, pour lesquels le délai en question expire le 15 janvier, à savoir : Districts de Fouah, Dessouk, Kafr el Cheikh et Cherbine, dans la Moudirieh de Gharbieh; Districts de Rosette, Kafr el Dawar et Abou Hommos, dans la Moudirieh de Béhéra; Districts de Dekernès et Fareskour, dans la Moudirieh de Dakahlieh.

In practice, however, there is or used to be considerable laxity with regard to the growth of bamia (*Hibiscus esculentus*). This plant, although not grown in large areas, is grown in small lots almost everywhere,

since it is a very favourite vegetable in Egypt, and so it may have an importance as regards the pink bollworm problem. In their own interests cultivators will do well to abstain from growing bamia as a perennial in order to obtain an early supply of the fruits and consequently a higher market price.

The practice of growing cotton-okre — that is cotton which is kept in the ground for two consecutive years — as is practiced in some parts of the Northern Delta should preferably be given up, since it is liable to afford the pink bollworm material assistance to maintain its hold in districts where this form of culture is in vogue.

DESTRUCTION OF THE INFESTED BOLLS.

The destruction of *all* bolls remaining on the plants after the last picking of cotton has been taken is now provided for by the aforementioned Decree as recently amended by the Ministry of Agriculture, which says :—

DESTRUCTION DU VER DE LA CAPSULE DU COTON.

Loi n° 4 du 20 juin 1914, modifiant la Loi n° 19 de 1912 portant les Mesures à prendre pour la Destruction du Ver de la Capsule du Coton.

Art. 1er. — Il est ajouté à l'article premier de la loi sus-visée* un troisième alinéa ainsi conçu :—

Chaque année, après la récolte, toutes les capsules encore adhérentes à ces plants devront être enlevées et brûlées.

Cette opération devra être exécutée, au moins quinze jours, avant les dates respectivement fixées ci-dessus pour chaque province, pour l'arrachage ou la coupe des racines des plants et dans tous les cas avant qu'il ne soit procédé à cet arrachage ou cette coupe.

Art. 2. — Il est ajouté à l'article 3 de la loi sus-visée un second alinéa ainsi conçu :—

En cas de contravention au troisième alinéa de l'article premier, les plants seront toujours saisis et brûlés, qu'ils aient été ou non arrachés ou coupés.

The removal and destruction of bolls has not so far been properly carried out for reasons already mentioned, but it is hoped that this will be done in the future, since not only will it benefit the country as a whole but each individual cotton grower. The measure is not one that

should weigh heavily on or be impossible for the small cultivators possessing one or a few feddans of cotton only, since as it is, they are (or were before the advent of the pink bollworm) accustomed to pick off all unripe green bolls which they think will give some fibre after being baked in their bread ovens. It would thus not be such a heavy task as may appear at first sight for them to pick *all* the bolls off, burning those of no use and treating the others in the manner described.

For the small grower, the question of the practicability of the hand picking of bolls is one of the time necessary for the operation rather than of the actual cash cost to him. The fellah is, as a rule, impatient to get the crop following cotton in immediately, and so he is very inclined to grudge the few days required for complying with the law and removing the bolls from the plants before they are pulled up.

The oven ripening process, in which the green bolls are placed in the still hot oven after a batch of bread has been baked, seems fatal to the pink bollworm larvæ as is shown by the following trials made in a small bread oven constructed for the purpose.

EXPERIMENT N° 1.

27TH NOVEMBER 1913.

Placed 26 green bolls on a Marseilles roofing tile on floor of oven at 11.30. Temperature 144° C.

State of fire :— glowing ashes.

Removed 6 Bolls (Lot 1) at 12.10 p.m. 27th November. Temperature before door was opened was 152° C.

Result :

All six bolls still quite wet inside. Found 16 dead pink bollworms and 1 *Earias* larva. All appeared to have been steam boiled.

No living larvæ.

Removed remaining 20 bolls (Lot 2), 9 a.m. 28th November. Bolls dry. Found 28 dead Pink Bollworms which were dry.

No living larvæ.

EXPERIMENT N° 2.

27TH NOVEMBER 1913.

10 green bolls placed in oven at 12.50 p.m. on Marseilles tile on floor of oven. Temperature 133° C.

Removed bolls 9 a.m. 28th November. Temperature of oven 22° C.

Result :

Examined the 10 dried bolls 30th November. Found 12 pink bollworms dead and dry.

No living larvæ.

EXPERIMENT N° 3.

27TH NOVEMBER 1913.

20 green bolls placed on Marseilles tile on floor of oven at 4.40 p.m. 27th November. Temperature of oven 80° C.

Removed partially dried bolls 9 a.m. 28th November. Temperature of oven 22° C.

Result :

Examined the 20 bolls 30th November. Found 38 dead pink bollworms and 1 *Earias*. They were not dried up and hard as in Experiment No. 1, Lot 2 and Experiment No. 2.

No living larvæ.

EXPERIMENT N° 4.

2ND DECEMBER 1913.

Placed 20 green bolls in oven 10.45 a.m.

10.45 a.m. Temperature = 98° C.

11.30 — — = 73° C.

1 p.m. — = 55° C. Bolls removed.

Result :

Found 28 dead pink bollworms and 3 dead *Earias*. Bodies were not dry.

No living larvæ.

To turn to the owners of large areas of cotton, from fifty feddans upward; here the case is rather different, for money has actually to be paid out for the operation of removing the bolls, whereas in the case of the fellah owner the work should be (or so one would think) within the power of himself — if he is prepared to give or will make the time necessary for the operation — together with the members of his family to accomplish, and thus the work does not cost him anything in cash.

The cost of hand picking the bolls from an area of one feddan will vary very considerably according to the size of the plants, number of bolls left, amount and cost of labour available. It may be a low as 20-25 piastres (4 s. to 5 s.) but this figure may be doubled or even trebled in cases where the plants grow very tall and rank and labour is scarce and dear. Thus when hundreds of feddans are involved, boll-picking is by no means an inconsiderable item to be added to the expense of the cultivation necessary to produce cotton, since this particular operation is (and must be regarded as such) just as much part of the cultivation rutine for this crop as the operations of sowing, watering, hoeing, and harvesting.

The cost per feddan will of course be returned many times over by the increased yields obtained from the working of this simple control measure provided it is carried out thoroughly and by everyone. But for one cultivator to do this work, whilst his neighbours neglect to do so, is useless and is both a waste of time and money. This was demonstrated on the Society's own farm at Bahtim in 1914, the attack during the past season being more severe than that of 1913 in spite of the fact that the whole of the bolls were removed and burnt before the plants were pulled up, but on the surrounding lands nothing was done.

In addition to the question of the cost of the operation being regarded as a drawback, there is another and more important matter to be considered, but which, however, is of greater moment in the North than in the Middle Delta and Southern Egypt. In the North the last picking of cotton fibre is as a rule not taken until very late — November and sometimes even in December — and thus little time is left to get the cotton plants out and get the land ready for the following crop — wheat, barley,

beans, or perhaps berseem. The extra time required to pick off the bolls before pulling the plants causes considerable delay and so becomes a matter of great importance. The only plan to circumvent this difficulty seems to be to combine the last picking of cotton fibre and the boll picking into one operation, the children and women who are employed for this work putting the fibre in one receptacle and the bolls in the other. Of course the work will take longer so than if the fibre alone was gathered and the cost will be proportionally higher, but some saving of time will result. Another alternative — and one which will be no doubt be practiced in a great number of cases where the direct or indirect cost of hand-picking the bolls is likely to equal or exceed the value of the sticks as fuel — is to remove the plants with all the bolls still on them, place them in heaps of suitable size on the field, or if more convenient on the borders of the field, and as soon as the sticks will burn set fire to them. The ashes will have some manurial value and can be returned to the land.

METHODS OF DESTROYING THE USELESS BOLLS OTHER THAN REMOVAL BY HAND PICKING.

The State Domains have found that to turn large flocks of sheep into the cotton is a most successful way of destroying the bolls left on the plants after the last picking. These animals will eat all the leaves and green bolls as well as most of those which are dead and dry within their reach. Goats will do the same in even a cleaner manner than sheep. This is both a very quick and quite effective method and, moreover, it has the advantage of not only costing nothing, but is a distinct gain, since the owners actually pay to allow their sheep to run on this feed. How completely the sheep do their work is illustrated (although not very well) by the photographs on Plate X, Figs. 1 and 2. Where berseem has been sown amongst the standing cotton plants sheep, cannot of course be employed.

Mr. H. C. Jefferys of the State Domains Administration has worked out another excellent way of utilizing sheep for boll destruction work in those

cases in which cotton sticks have *had* to be pulled before the bolls have all been removed and put up in heaps or koms on the boundaries of the field, or else laid out along a canal bank, etc. Later on these sticks will be required for fuel in the pumping engines. As soon as convenient a day's supply of sticks is transported from the *kom el hatab* (heap of sticks) in the field to the neighbourhood of the pumping engine, where it is spread out on the ground and then sheep are turned on to it. The animals eat off all the dead bolls, apparently being attracted by the seed and juicy bollworms they contain. As soon as the sticks are clean they are collected and built up into a heap ready at hand to be utilized in the engine when irrigation becomes necessary in the spring or summer. This work is repeated until the whole of the supply of sticks destined for the furnace of some particular engine has been transported from the field, cleaned of bolls, and re-stacked ready for use. The sheep are allowed to pick up all bolls which may have fallen off in the handling after the sticks have been picked up off the ground each day.

This seems to be a very practicable and effective way of dealing with plants which have been pulled before the removal of the bolls, as of course it entirely does away with the danger of the resting larvæ giving rise to moths if the sticks and bolls remained unburnt until June and July or later. Furthermore, expense is saved and time also at a period when every day lost in boll picking in the field is an important consideration.

MECHANICAL METHODS FOR REMOVING BOLLS FROM COTTON PLANTS.

The Ministry of Agriculture has introduced several simple implements for combing the bolls off the plants. The sticks are removed and carried to one or more points where they are pulled through iron plates fastened to a stout piece of wood driven into the ground and having in the middle a V-shaped notch provided with a cutting edge. The other form consists of a series of iron spikes forming the comb such as is used for preparing teel for rope making and also flax fibre in Egypt.

These implements are said to give very satisfactory results and are very cheap to make.

As soon as it is generally realized that all remaining bolls *must be destroyed* at the end of the season if the pink bollworm is to be controlled, the growers will no doubt find the most effective and economical way of accomplishing this according to their circumstances.

It should be possible perhaps to construct a horse, mule, or bullock-drawn machine for removing the bolls; but it will be essential that any machine of this sort must not remove the bolls, only to let a great number fall on to the ground; to be of practical use it will have to remove the bolls cleanly and collect them at the same time.

In any case, it may in the future be necessary to collect the fallen bolls on the ground into heaps by some form of harrow, and to destroy them.

Removal of the bolls by machine (if feasible) would no doubt lower the cost per feddan for this operation, but such a method will only be practicable on moderate sized or large estates : it will not solve the question for the small growers — by whom a large bulk of the cotton is grown — and they will always have to pick off the bolls by hand if they wish to save the sticks for fuel; or their other alternatives will be to employ sheep or goats to do the work; or again, to pull up the plants and burn them at once.

RECOMMENDATIONS

WITH REGARD TO STORING COTTON STICKS.

The following points no longer apply if the terms of the Bollworm Decree are carried out and sticks are stored free of bolls, but they are mentioned as being of interest, since they serve to illustrate past, or rather what it is hoped will become past, practices :—

I. — «Gilleh Cakes» (cakes of dung, mud, and perhaps some tibn or chopped straw, used for fuel) should never be plastered over cotton sticks bearing bolls stored on house tops and elsewhere in the villages

and ezbehs. To do so is an additional protection to the resting pink bollworms as it shields the bolls from the effect of the sun heat.

I am informed that the villagers in the north of the Delta not infrequently practice this method as being a convenient way of storing and at the same time drying this dung-cake fuel.

II. — It is better to store sticks in the field in as few heaps or *koms* as possible, since after the wood has been removed to be used up as fuel all bolls which have been broken off and gradually sifted down to the kom bottom can with little trouble be raked together and burnt. This should always be done. If, however, a number of small heaps have been made, this precaution is much more likely to be overlooked.

III. — It is a better practice to stack the sticks at once in heaps or koms (Plate X, Fig. 3) than to lay them out in a thick layer along the borders of the field (Plate X, Fig. 5) — generally a canal bank, because during the handling of the sticks many bolls are broken off and fall amongst the coarse grass and weeds, frequently growing on canal and road banks, over a much larger and more widespread area than is the case if the plants are collected together in a few heaps. In such surroundings as mentioned they and the resting pink bollworms they contain stand a good chance of being protected from the sun : under these circumstances the resting larvæ might survive and give rise to moths in June, July and August when they would be in a position to give rise to a fresh pink bollworm attack on the cotton.

IV. — A thick carpet of bolls should not be allowed to accumulate round pumping engines (Plate X, Fig. 4). The bolls which get broken off whilst the cotton sticks are being broken up into suitable lengths to be fed into the furnace should be gathered up each day and burnt.

V. — Cotton sticks *bearing bolls of any kind* should never be employed for making fences and cattle pens; the roofs of houses (as protection from the sun), and ghaffir's shelters; for making or repairing light bridges

across small canals and drains; for constructing, strengthening, or repairing earthen embankments and the sides of drains, etc.; nor for «sticking» peas, and all similar uses. It is essential that all bolls be removed from the plants and destroyed before the sticks are employed for any of the above purposes.

DESTRUCTION OF TEEL OR HEMP AND BAMIA SEED CAPSULES.

The destruction of seed capsules of teel and bamia are not provided for in the Bollworm Decree, but nevertheless attention should be paid to this matter, as both may be infested with resting pink bollworms, in some cases heavily so. The danger from this source of re-infection will depend of course on the extent to which these plants are left lying about in odd corners. In gardens for instance, old bamia plants are pulled up in the autumn with many dry capsules still attached and are then perhaps put away in a corner to be disposed of no one knows when. It would be a much safer practice to remove all seed capsules, take from them what seed is required for sowing and burn the rest.

Similarly, teel plants bearing seed capsules should not be allowed to lie about in ezbehs during the summer following that in which they were grown. As soon as practicable after the plants have been pulled up, the seed should be threshed out, sufficient good seed being kept for sowing purposes and the rest if found to be infested with pink bollworm had best be destroyed or hand-picked to remove the pest.

The bulk of the teel is so treated and the stems of the plants after the seed has been taken will either be burnt or put in a canal to soak and render them suitable for rope-making. However in some cases one does see small stocks of entire plants lying about and for this reason the danger is pointed out. Table XXVI (page 107) shows the number of resting larvæ present in various samples of teel obtained during the months of February and March. It appears to be a common practice to cut a large amount — in fact perhaps the bulk — of the teel at the time the first picking of

cotton is taken and to place the cut plants under water in a canal or drain. The soaking causes the rhind or outer covering and all the seed capsules to strip off. Thus in all probability any resting pink bollworms in the latter will be destroyed.

Teel seed can readily be freed from pink bollworm by hand-picking, because from 3 to 5 seeds are spun together (Plate IV, Figs. 17-18) and thus the resting cocoons of the pest are easily seen and may be removed by children. The same precaution applies to bamia or okra seed.

No volunteer growths of teel and bamia should of course be tolerated in the fields or gardens during the winter and early spring.

Bamia and teel plants should not be buried if they still bear seed capsules. If it is wished to destroy the plants, they should be burnt as soon as dry enough.

EARLY MATURITY OF THE CROP AS A SAFEGUARD AGAINST EXTENSIVE BOLLWORM INJURY.

The earlier the crop reaches maturity the less will be the loss experienced from bollworm attack, both that of the pink bollworm and the ordinary bollworm *Earias insulana*. The plant breeder thus has a great field for his skill in this direction, for if a variety of cotton could be obtained with all the desirable characteristics of the present Egyptian Afifi types, but which would give the bulk of its produce — say a month earlier, the financial gain to the country would, I think, be enormous. At present in many parts of the country the first picking even, is not ripe and free from danger of attack until the bollworm is well on the way to reaching its maximum numbers, the result being that this, the most important part of the crop, may and does suffer serious damage; whilst as regards the second and third pickings it is disastrous.

It is of course obvious that everything should be done culturally to encourage the early maturity of existing varieties and too late sowing should on all accounts be avoided. This is not done by many of the smaller cultivators who favour their berseem crop — leaving it on the

ground to the latest possible date — at the expense of their cotton, when the latter follows this forage crop. During the past year the writer received a number of reports of growers picking a good crop of cotton in spite of the severity of the pink bollworm attack and in all cases they attributed this success to early sowing and the bolls ripening in large numbers before the bollworms became too numerous. On the other hand, their neighbours, whose cotton was late, only picked half or in some cases less than half of the weight of cotton they were accustomed to obtain from their land. Furthermore, the proportion of inferior quality bollworm-damaged lint was very high.

It is recognized of course that the date of sowing is somewhat dependent on the weather and locality, but there is moderation in all things and where cotton can be sown with good chances of a successful stand of young plants being obtained — say in the first or second week in March it should on no account be postponed until the first week in April or even later.

DESTRUCTION OF THE PINK BOLLWORM IN COTTON SEED.

As regards this question, any efficient method of destroying the pink bollworm is of little value unless it can be employed on a commercial scale, because as we have already pointed out this control measure must be carried out by all if it is to be effective. The only way to obtain such a result appears to have the seed treated at the ginneries, preferably by a continuous process as the seed leaves the gins, so that each day's output of seed will have been freed from the pest at the end of the working day. Therefore, any process of destroying *Gelechia* larvæ that is suitable for dealing with small quantities of seed is of little concern to us; what is required is a system by which very large bulks of seed can be dealt with.

Before dealing with the larger question it will perhaps be of interest to mention one or two simple ways which have been recommended for

Table LI.

Effect of Immersion in a solution of Cyllin on the Resting Pink Bollworms in Double Cotton Seeds.

N° of sample.	Number of double seeds in sample.	Kind of Cyllin employed.	Strength of the solution.	Period of immersion.	Total number of larvæ found in sample.	Number of live larvæ after treatment.	Per cent of total.	Number of larvæ killed by treatment.	Per cent of total.	Number of larvæ killed by other causes.	Per cent of total.	Remarks.
1	20	Jeyes' Medical Cyllin.	5 cc. per litre of water	6 hours.	19	8	42	1? *	5.5	10	52.5	* Cause of death doubtful — whether effect of Cyllin or simple drowning?
2	20	— — —	10 — — —	6 —	18	10	55.5	1? *	5.5	7	39	
3	20	Jeyes' Fluid Cyllin.	5 cc. per litre.	6 —	20	13	65	4? **	20	3	15	
4	20	— — —	10 — —	6 —	18	8	44	1? *	6	9	50	** Cause of death doubtful in two cases — whether effect of Cyllin or simple drowning.
5	25	— — —	1 — —	12 —	24	16	66.6	2? *	8.4	6	25	
6	25	— — —	1 — —	24 —	23	17	74	4? *	17	2	9	
7	25	— — —	1 — —	24 —	24	15	62	2? ***	8	7	30	*** Larvæ affected only, not killed.
8	20	— — —	1 — —	24 —	17	11	65	0	»	6	35	
9	25	— — —	2 — —	6 —	24	16	66	0	»	8	34	

cleaning small lots of seed required for sowing purposes and which are infested with pink bollworm.

Hot water treatment. — One of the simplest of these appears to be the « Hot Water Treatment », the seed being put into a sack and immersed for a sufficient length of time in hot water of a certain temperature to destroy the pest. After treatment the seed must be dried at once and sown shortly afterwards, or it could, if required, be sown wet after treatment, by the « wet method » of sowing cotton seed.

The Deputy Director of the Cawnpore and other Experimental Stations in the United Provinces of India [56] appears to have first suggested this system. He found that seed soaked for 5 or 10 minutes in water of 130° F. (55.5° C) was effective in killing all the pink bollworms.

Dr. Gough and Mr. G. Storey [57] have also shown this method to be effective at this temperature, but recognize the fact that it is only suitable for small quantities of seed to be treated by the individual, and is therefore of no great account. Immersion in hot water at 55° C. does not impair the germination of the seed.

Cyllin treatment. — Dr. Gough [58] formulates a second simple process for treating seed under the same circumstances as above. This is to soak the infested seed in a solution of Cyllin 1 in 1000 for 24 hours. This is said to be effective in killing all the resting pink bollworms. After treatment the seed must be sown as soon as dry and watered immediately. Curiously enough the writer has had totally different results working with Jeyes' Medical Cyllin and Jeyes' Fluid Cyllin, both of which gave, practically speaking, negative results at 1 : 1000 and 1 : 500 for 24 hours. Nor was the treatment successful if employed much stronger for a shorter period. It is true that if the seed is examined immediately after treatment many larvæ will be found *apparently* dead, but if they are kept, all or the majority will be found to have revived at the end of 24 hours and to be in a normal condition. The same fact has been noted if seed is soaked in plain water. The experiments with the brands of

Table LII.

The Effect on the Resting Pink Bollwo

Number of Sample.	Date of Treatment.	Weight of Sample.	Approximate Number of Seeds in Sample.	Duration of the Immersion in Water.	Total Number of Larvæ in Seeds.	Number of Live Larvæ after Treatment.	Per Cent of Total Larvæ.	Number of Larvæ Drowned.	Per Cent of Total Larvæ.
1	15 April, 1913.....	30 grams.	372	6 hours.	15	12	80		
2	—	—	—	12 —	14	10	71.5		
3	—	—	—	18 —	12	10	83		
4	—	—	—	24 —	12	9	75		
5	—	—	—	30 —	14	7	50		
6	—	—	—	36 —	13	7	53		
7	—	—	—	42 —	18	11	61		
8 [1]	—	—	—	48 —	10	0	0		
9	—	—	—	60 —	12	6	50		
10	—	—	—	72 —	11	3	27		
11 [2]	21 April, 1913.....	41 double seeds.	—	24 —	29	24	82.8	2 [3]	6.9
12 [2]	—	50 —	—	48 —	39	21	54	7 [3]	18
13	13 May, 1913.....	10 gms double seeds.	70	6 —	36	18	50	3	8.5
14	—	—	—	12 —	34	12	35	11 [4]	32
15	—	—	—	18 —	40	15	37.5	0	0
16	—	—	—	24 —	35	8	23	11 [4]	32
17	—	—	—	30 —	44	11	25	4	9
18	—	—	—	36 —	42	14	33	2	5
19	—	—	—	42 —	50	16	32	5	10
20	—	—	—	48 —	41	14	34	1	2
21	—	—	—	60 —	41	19	46	11 [4]	27
22	—	—	—	72 —	36	16	44	12 [4]	33
23	24 January, 1914....	100 double seeds.	—	69 —	74	41	55	21	28

Immersing the Infested Seed in Water.

NUMBER OF LARVÆ KILLED BY MITES.	PER CENT OF TOTAL LARVÆ.	NUMBER OF LARVÆ KILLED BY DISEASE, ETC.	PER CENT OF TOTAL LARVÆ.	TOTAL MORTALITY FROM ALL CAUSES.	PER CENT OF TOTAL LARVÆ.	REMARKS.
				3	20	
				4	28.5	
				2	17	
				3	25	
t Recorded.				7	50	
				6	47	
				7	39	
				10 [1]	100	[1] Possibly an error has been made here.
				6	50	
				8	73	
3	10.3	0	0	5	17.2	[2] Samples 11 and 12 were placed in the middle of a sack of cotton seed which was the immersed in water.
7	18	4	10	18	46	[3] Cause of death uncertain.
4	11.5	11	30	18	50	
10	30	1	3	22	65	
21	52.5	4	10	25	62.5	
10	28	6	17	27	77	[4] Cause of death not certain in all cases. A number of larvæ may have been killed by mites (*Pediculoides ventricosus*).
21	48	8	18	33	75	
23	55	3	7	28	67	
24	48	5	10	34	68	
22	53	4	11	27	66	
9	21	2	6	22	54	
8	23	0	0	20	56	
3	4	9	13	33	45	

Cyllin mentioned are given in Table LI. From 20 to 25 «double seeds» containing resting pink bollworms were loosely tied up in a piece of muslin and immersed in a beaker containing the solution. The bag was moved up and down to expell air and was afterwards kept immersed by means of a small weight. At the end of the treatment the seed was spread out on a sheet of paper and allowed to dry. Examination was made 24 hours after treatment. Most of the dead pink bollworms found had been killed by mites (*Pediculoides ventricosus*), or by disease their bodies being dry and hard. As regards those larvæ which had died recently, a small number only, it was difficult to say whether they had been killed by the action of the Cyllin or had been drowned.

In view of these experiments, Cyllin would appear to be very uncertain in its action on the pink bollworm.

IMMERSION OF SEED IN WATER.

DESTROYING THE PINK BOLLWORM BY DROWNING.

In March 1913 a letter was received from Mr. Crewe Coles, of the State Domains, in which he stated he had observed in the case of cotton seed that was being sown by the «wet method» and consequently had been soaked in water for 24 hours previous to being sown, that the pink bollworms were dead, apparently having been drowned in the process. In order to ascertain the possible utility of treating cotton seed in this manner to free it from the pest a number of trials were made, the results of which are tabulated in Table LII. From these it will be seen that soaking the seed in water is, practically speaking, useless, since it is impossible to drown a sufficiently high percentage of the resting pink bollworms in a reasonable period.

If seed is examined immediately after treatment the larvæ are found to have been *apparently* drowned, but later they revive and become quite normal again. For this reason all seed which had been soaked was not examined until one to several days had elapsed.

It is true that the total mortality in seeds which have been soaked is

greater (*vide* Control Table LIII), but this seems due to the work of the predaceous mite, *P. ventricosus*, rather than to death by drowning. The mite appears to be particularly active in the presence of moisture and a high temperature. As a matter of fact it was difficult on account of the mites to say whether death was primarily due to drowning or to the attacks of these parasites. However, considering the large number of live larvæ present in most of the treated samples and also that the mites did not appear to have been effected by immersion, it seems not unlikely that even fewer larvæ were actually drowned than is shown on the record, in which the treatment has been credited with the maximum effect.

Table LIII.

Control Seeds for Samples 13-23 in Table LII.

NUMBER OF SAMPLE.	DATE EXAMINED.	WEIGHT OF SAMPLE.	NUMBER OF SEEDS IN SAMPLE.	TOTAL NUMBER OF LARVÆ IN SEEDS.	NUMBER OF LIVE LARVÆ.	PER CENT OF TOTAL LARVÆ.	NUMBER OF LARVÆ KILLED BY MITES.	PER CENT OF TOTAL LARVÆ.	NUMBER OF LARVÆ KILLED BY DISEASE, ETC.	PER CENT OF TOTAL LARVÆ.	TOTAL MORTALITY FROM ALL CAUSES.	PER CENT OF TOTAL LARVÆ.
1	11 May 1913.	10 grams	70	45	34	75.5	4	9	7	15.5	11	24.5
2	—	of	72	52	39	75	6	12	7	13	13	25
3	—	double seeds.	71	56	39	70	7	12	10	18	17	30
Totals.....		30 grams.	213	153	112	73	17	11	24	16	41	27

It has been noticed in the case of double cotton seeds, containing resting pink bollworms, sown in wet soil that the cocoons become abnormally tough and difficult to break open. Possibly this may be due to the larva fortifying its cocoon against moisture by spinning additional layers of silk, a supply of which it always has at its command. The larva might well behave in such a manner when it found its abiding place under

water and in danger of being flooded. The cocoon is too finely woven to permit of water passing through, one would think, so worms that *are* drowned *in situ* must either have spun themselves up insecurely or else possibly although hardly probably, I think, the action of the water gradually breaks down the cocoon if the larva cannot continually add to its strength by spinning fresh walls of silk behind the original one.

Death can hardly have been due to simple suffocation (without any water entering the cocoon) owing to exhaustion of the available air supply or else all the larvæ would have been similarly effected, the difference in the air space in the different seeds or cocoons harbouring the pink bollworms hardly being sufficient to account for the great difference in the mortality shown by the experiment.

DESTRUCTION OF THE PINK BOLLWORM IN COTTON SEED BY EXPOSURE TO SUN HEAT.

The commonest way of destroying insects infesting grain, clothes, carpets, etc., employed by the people of Egypt is to place the grain, etc., on the ground fully exposed to the sun. This method, during the greater part of the year, is very effective.

Cotton seed can be freed from the pink bollworm by this system. The length of time it will be necessary to expose it will depend of course on the thickness of the layer in which it is spread out on the ground, and on the time of the year. The thinner the seed is spread out the better; if it is in a thick layer it must be turned several times to expose the bottom cotton seeds. In February and March there are many days when the sun is not sufficiently hot to kill the pink bollworms. On the other hand, there are days when the pest can be destroyed in a short time if the seed is placed in a very thin layer on the ground. Owing to this uncertainty, the method is of no practical importance in this instance, since it might well happen that when one wished to treat the seed the day would be dull or cool, or there might be a spell of unsuitable weather for the operation. Moreover, for a few individuals to treat their tagawi seed is of no value.

In May it is possible to destroy the pink bollworm in cotton seed in this manner in a very short time without prejudicing its germination capacity. Table LIV shows the results of exposing 3 samples of infested cotton seed (double seeds) to the sun in mid-May 1913.

Table LIV.

THE EFFECT OF SUN HEAT ON THE PINK BOLLWORM IN COTTON SEED.

NUMBER OF SAMPLE.	DATE WHEN EXPOSED.	DURATION OF EXPOSURE.	TEMPERATURE IN SUN ON GROUND.	TOTAL NUMBER OF PINK BOLLWORMS FOUND IN SAMPLE.	AFTER EXPOSURE NUMBER OF LIVE PINK BOLLWORMS.	PER CENT OF TOTAL.	NUMBER OF PINK BOLLWORMS KILLED BY EXPOSURE TO SUN HEAT.	PER CENT OF TOTAL.
A	14 May, 1913....	5 minutes...	59°-60° C.	19	10	52.6	9	47.4
B	14 —	10 — ...	59°-61° C.	24	0	0	24	100
C	14 —	15 — ...	59°-62° C.	18	0	0	18	100

REMARKS. — Double seeds were used. These were placed in a thin layer on a sheet of newspaper exposed to full sunshine. Bulb of thermometer was covered with a piece of dark cloth.

For control seed — see Table LIII.

Equally good results have been obtained in the first week in March. It has been observed that the larvæ do not — except in rare cases — attempt to leave the seed when it is exposed to the sun but remain and are killed *in situ*.

EFFECT OF SUN HEAT ON PINK BOLLWORMS IN COTTON SEED SOWN IN DRY SOIL.

Mr. Victor Mosseri suggested to the writer that possibly sun heat might be utilised to kill the pink bollworms infesting tagawi cotton seed after it had been put in the ground, by allowing an interval of two or three

Table LV.

Effect of Sun Heat on Pink Bollworms in Cotton Seed sown in Dry Soil.

1 DATES ON WHICH SEED WAS EXPOSED.	2 NUMBER OF DAYS EXPOSED.	3 NUMBER OF DOUBLE SEEDS EXAMINED AFTER EXPOSURE.	4 TOTAL NUMBER OF PINK BOLLWORMS FOUND.	5 NUMBER OF LIVE PINK BOLLWORMS.	6 PER CENT OF TOTAL (4).	7 NUMBER OF PINK BOLLWORMS DEAD AND DRIED UP.	8 PER CENT OF TOTAL (4).	9 NUMBER OF PINK BOLLWORMS KILLED BY MITES.	10 PER CENT OF TOTAL (4).	11 TOTAL NUMBER OF DEAD PINK BOLLWORMS.	12 PER CENT OF TOTAL (4).	13 NUMBER OF DOUBLE SEEDS CONTAINING NO PINK BOLLWORMS.	14 PER CENT OF TOTAL (3).	15 REMARKS.
1915.														
April 2nd to 11th.	10 days.	137	99	28	28.2	70	70.7	1	1	71	71.7	38	27.8	Possibly some larvæ
— 12th to 17th.	5 —	300	212	80	37.7	96	45.7	36	16.6	132	62.3	88	29	may have vacated seed
— 22nd to 25th.	3 —	186	138	65	47	59	42.7	14	10.3	73	53	48	25	when in soil.

Seeds sown in «holes» at a depth of 4 cm.

Table LVI.

Control Double Seeds.

1 DATE.	2 NUMBER OF DOUBLE SEEDS EXAMINED.	3 TOTAL NUMBER OF PINK BOLLWORMS FOUND IN (2).	4 NUMBER OF LIVE PINK BOLLWORMS IN (2).	5 PER CENT OF TOTAL (3).	6 NUMBER OF PINK BOLLWORMS DEAD AND DRIED UP.	7 PER CENT OF TOTAL. (3).	8 NUMBER OF PINK BOLLWORMS KILLED BY MITES.	9 PER CENT OF TOTAL (3).	10 TOTAL NUMBER OF DEAD PINK BOLLWORMS.	11 PER CENT OF TOTAL (3).	12 NUMBER OF DOUBLE SEEDS CONTAINING NO PINK BOLLWORMS.	13 PER CENT OF TOTAL (2).
4 April, 1915.	250	210	120	57	64	30.5	26	12.5	90	43	40	16

days to elapse before watering. During this time it was thought that the seed in the dry soil might be heated up to a sufficiently high temperature to be fatal to the pink bollworm.

In order to test this, some preliminary trials were made in the laboratory garden, the seed (double seeds) being planted on the sides of dry ridges (soil very sandy) well exposed to the morning and afternoon sun from 10 a. m. to about 4 p. m.

The results are given in Table LV from which it will be seen that even in April after an interval of 3 up to 10 days in the dry hot soil many larvæ survived, although some appear to have been killed by the exposure to these conditions (see Control Seeds, Table LVI). In February and March the effect would tend to be less, unless an abnormally hot spell was experienced during the time the land sown with seed was in a dry state.

THE DESTRUCTION OF THE PINK BOLLWORM IN COTTON SEED ON A COMMERCIAL SCALE.

For the destruction of the pink bollworm in cotton seed on a commercial scale two methods present themselves for consideration, viz. :

I. Fumigation with a poisonous gas.

II. Treatment by heat — that is, to subject the seed to a temperature high enough and for a sufficient length of time to be fatal to the bollworm, but not so high as to adversely effect the germinating powers of the seed, nor the oil contained in the kernel.

As regards the first method — fumigation — there are at present two gases which it seems practicable to employ :—

A. Carbon Bisulphide, and

B. Hydrocyanic Acid Gas.

Unfortunately attached to the use of both there are certain disadvantages. The former in its liquid state is very inflammable and when vapourized and mixed with a certain proportion of air the mixture is highly

explosive and easily ignited. The vapour of carbon bisulphide is poisonous and must not be breathed for any length of time in a confined space or serious results may follow. A further disadvantage of a different nature is the fact that although carbon bisulphide vapourizes very readily and the resulting gas is heavier than air, yet it is only able to penetrate very slowly through a mass of cotton seed or to enter the cocoons of the pink bollworms spun up inside the seeds, unless special apparatus is employed to speed up the process.

On account of its inflammable and explosive nature the employment of carbon bisulphide in or in the vicinity of expensive buildings and machinery presents some difficulty, owing to the question of their insurance; special insurances have to be taken out at much higher premiums than ordinarily would be the case. For the same reason sea and rail freights for this substance are high, so that its cost is considerably advanced in countries where it is not manufactured. Yet another drawback is the fact that there is a strong possibility that the oil in the cotton seeds may be affected chemically by the carbon bisulphide vapour owing to the latter being absorbed by the kernels of the seed.

Hydrocyanic acid gas, in addition to possessing only a very low power of penetration, has the further disadvantage of being one of the most deadly gases known to human and animal life. It has to be used therefore with great care, especially in confined spaces; any carelessness may well lead to fatal results. Similar care has to be exercised with regard to the chemicals from which this gas is prepared — potassium or sodium cyanide and commercial sulphuric acid.

The drawbacks incident to the use of these two gases led the writer at first to consider the possibilities of and also to favour the employment of heat as a means of destroying the pink bollworm in cotton seed. The bias towards this method was strengthened perhaps by the success obtained by Dean [59] in America with the employment of steam heat for controlling insect pests in mills, both in the machinery, floors and walls, as well as in stocks of flour and grain in these buildings. However, the recent work carried out with carbon bisulphide and hydrocyanic acid

gas by the Ministry of Agriculture; and more recently still by Mr. Victor Mosseri, who has successfully demonstrated the great value of hydrocyanic acid gas when used in vacuo for the destruction of the pink bollworm in cotton seed, has led the writer to somewhat modify his opinion and it is now recognized that destruction by heat may be found to be the least practicable of the two methods on account of, the first cost of installation, working expenses, repairs bill, and output of treated seed per day, being in favour of the gas treatment. The disadvantage of the poisonous nature of hydrocyanic acid gas must be met by the observance of extreme care on the part of those using it — no attempt being made to employ unintelligent but cheap labour to carry out the process.

I. — TREATMENT OF THE SEED BY HEAT.

Table LVII shows that the pink bollworm in cotton seed succumbs to a very much lower temperature than is at all prejudical to the germination capacity of the seed. These trials were made in an ordinary chemical drying oven, the seed being placed in paper trays on the middle shelf of the oven so that, practically speaking, the seed was on a *metal surface*. It was found, as expected, that a temperature of 50° C. continued for a short period was fatal to the larvæ. It is essential that this temperature be maintained for a short time, since experiments made by the writer have shown that the pink bollworm can withstand a temperature of 50° C. for a very short time — if it is removed to a normal temperature again immediately the thermometer registers 50° C.; and although it may be removed in an apparently lifeless condition or at the best showing occasional and feeble twitchings of the body, it will afterwards recover its normal activity and be seemingly none the worse for its experience. Some larvæ appear to be able to stand higher temperatures than others. From 35° to 40° C. larvæ become very active indeed to distressed; from 40° to 45° distress gives place to convulsions, exudation of drops of liquid from the mouth and, gradually, quiescence. After about 47° or in some cases before the larva loses all powers of crawling and, generally speaking, when

Table LVII.

Effect of Exposure to Heat on the Resting Pink Bollworms in Cotton Seed.

Number of sample.	Date of treatment.	Number of double seeds treated.	Duration of treatment.	Minimum temperature during treatment.	Maximum temperature during treatment.	Total number of larvæ in sample.	Number of live larvæ after treatment.	Per cent of total.	Number of larvæ killed by heat.	Per cent of total.	Number of larvæ killed by mites.	Per cent of total.	Number of larvæ killed by other causes.	Per cent of total.	Total mortality from all causes.	Per cent of total.	Germination of treated seed.		
			*														Number of seeds in test.	Temperature at which germinated.	Per cent germinated.
1	May 1913.	48	30	35°	38°	35	27	77	0	»	3	8	5	15	8	23	100	28-30°	88
2	—	47	15	40°	44.5°	35	23	66	1?	3	4	11	7	20	12	34	100	—	93
3	—	49	30	40°	44.5°	44	30	68	0	»	7	16	7	16	14	32	100	—	85
4	—	50	45	40°	44°	39	26	67	0	»	6	15	7	18	13	33	100	—	90
5	—	50	60	40°	43°	39	28	72	0	»	5	13	6	15	11	28	100	—	91
6	—	48	15	49.5°	43.25°	39	0	»	33	84	4	10	2	6	39	100	100	—	85
7	—	48	30	49.5°	54°	36	0	»	25	70	4	11	7	19	36	100	100	—	94
8	—	50	45	50°	51.5°	45	0	»	31	70	1	2	13	28	45	100	100	—	90
9	—	52	60	50°	51.5°	42	0	»	30	72	6	14	6	14	42	100	100	—	90
10	—	48	30	59°	63°	34	0	»	22	65	7	20	5	15	34	100	100	—	88
11	—	53	7	68°	70.5°	42	0	»	30	71	4	10	8	19	42	100	100	—	91
12	—	49	15	59°	64°	34	0	»	22	65	7	20	5	15	34	100	100	—	83

* Minutes.

50° C. is reached, will be lying on its side or back motionless. A few minutes at this temperature is fatal, death being due to the coagulation of certain of the proteids in the body.

Table LVIII shows the results of shorter exposures to higher temperatures. In this case the «double seeds» used for the trial were divided into two lots. Series (A) were placed on a pad of ordinary good quality blotting paper 12 sheets thick on the middle tray of the drying oven. Series (B) were placed on a sheet of note paper on the bottom of the oven. The temperature of the air and water was noted before the seed was put in and on removal. From the result given by the 2 minute exposure it will be seen that a great deal depends on the nature of the surface on which the seed is exposed. This has been pointed out by Dr. Gough and G. Storey[60].

Now as regards the application of the heat for the destruction of the pink bollworm on a large scale : the original idea of the writer was as follows. A large, or a series of large, strongly constructed elevated bins or rooms would have to be constructed. These would be fitted with steam pipe radiators; the necessary area of heating surface required to raise a known quantity of seed to a given temperature in a certain time being carefully calculated. The steam would be supplied from an auxiliary boiler or from the main boilers of the ginning factory. If it were possible to run the steam heating from the latter or to utilize exhaust steam, a considerable economy would result. The cotton seed as it comes from the gins would be carried by a system of elevators to the top of the bins into which it would fall by gravity. In the bin it might have to be distributed by manual labour. When full the bin would be closed and the steam turned on and the whole mass heated up to the desired temperature and kept at that temperature for a certain period. The latitude available between the temperature fatal to the pink bollworm and prejudicial to the germination of the seed is so considerable that practicable temperature control should present no insurmountable difficulties.

Whilst one or more bins were being steam heated others would be filling or emptying. To empty the bin there would be a controllable

Table LVIII.

Effect of Heat on Resting Pink Bollworms in Double Cotton Seeds.

Number of Sample.	Number of "Double Seeds" Treated.	Duration of Exposure to Heat.	Temperature in Oven before Seed was put in.		Temperature in Oven when Seed was removed.		Total Number of Larvæ in Seeds.	Number of Live Larvæ after Treatment.	Per Cent of Total.	Number of Larvæ killed by Exposure to Heat.	Per Cent of Total.	Number of Larvæ killed by Mites.	Per Cent of Total.	Number of Larvæ killed by other Causes.	Per Cent of Total.	Total Mortality from all Causes.	Per Cent of Total.
			Temperature of Air.	Temperature of Water.	Temperature of Air.	Temperature of Water.											
		Minutes.															
1	10	2	"	70° C.	69° C.	81.75° C.	10	9	90	0	"	0	"	1	10	1	10
1ª	10	2	"	70° C.	69° C.	81.75° C.	10	0	"	9	90	0	"	1	10	10	100
2	10	4	71°	81.75°	71°	81°	10	0	"	8	80	1	10	1	10	10	100
2ª	10	4	71°	81.75°	71°	81°	8	0	"	4	50	0	"	4	50	8	100
3	10	6	71°	80.5°	71.5°	79.5°	9	0	"	7	77	0	"	2	23	9	100
3ª	10	6	71°	80.5°	71.5°	79.5°	9	0	"	7	77	0	"	2	23	9	100
4	10	8	71°	80.5°	73°	81°	8	0	"	5	62.5	0	"	3	37.5	8	100
4ª	10	8	71°	80.5°	73°	81°	10	0	"	4	40	1	10	5	50	10	100

1. Seeds placed on middle shelf of oven on a thick pad of blotting paper — 12 single sheets thick.

1ª. On sheet of writing paper on floor of oven.

2-2ª, 3-3ª; 4-4ª. As above 1 and 1ª.

opening in the bottom, the seed falling on to a travelling band to be cooled down to air temperature by passing under or through a current of air from a rotary fan, before being finally sacked. If the seed went straight from the gins into the heating rooms or bins, and from there after treatment to the cleaning and separating machinery the passage through the latter might be sufficient to cool the seed down to a temperature at which it could be sacked.

The point in the circuit made by the seed from the gins to the sacks at which the apparatus for destroying the pink bollworm will be installed is an interesting and at the same time an important consideration. Preferably the seed should pass *via* the seed transporter direct from the gins to the heat or gassing machine as the case may be, and from there to the cleaning machinery and so to the sack. But whether this will be possible in all cases will no doubt depend on circumstances as regards the existing construction and arrangement of machinery in the ginnery.

In discussing this system early in 1913 with Mr. Victor Mosseri certain serious disadvantages were pointed out to the writer. The first of these was the slowness with which large bulks of seed could be raised to a temperature fatal to the pink bollworm. Secondly there was the probability of the seed nearest the radiators reaching too high a temperature and being subjected to this temperature for too long a period. This would result in all probability in a lowering of the germination powers of the seed.

Further discussion on the same subject with three friends, Mr. F. Hughes, F.I.C., Mr. W.L. Balls, M.A., and Mr. H.C. Jefferys, led to another disadvantage being named, viz., that by this method the treatment of the seed would not be continuous and it was highly desirable that it should be. As a remedy it was suggested by Messrs. Hughes and Balls that the seed be carried straight from the gins through a hot chamber on an endless travelling belt or series of belts, the time the seed was exposed to the effect of heat being regulated by the length of the hot chamber and the number and speed of the belts. To heat the chamber, radiators supplied with high pressure steam appeared to be the simplest

Table LIX.

Effect of Exposure to Heat on Resting Pink Bollworms in Double Cotton Seeds. (January 1914.)

State Domain's Heat Machine for Treating Cotton Seed.

Number of Sample.	Average air temperature inside machine during treatment of seed.	Duration of exposure to heat.	Number of double seeds examined.	Total number of larvæ found in double seeds.	Number of live larvæ found in double seeds.	Per cent of total larvæ.	Number of larvæ killed by exposure to heat.	Per cent of total larvæ.	Number of larvæ killed by mites.	Per cent of total larvæ.	Number of larvæ killed by other causes.	Per cent of total larvæ.	Total mortality from all causes.	Per cent of total larvæ.	Remarks.
		Minutes.													
1	62.1° C.	7	500	387	0	0	249	64	0	0	138	36	387	100	
2	"	4	500	399	235	59	12	3	17	4	135	34	164	41	
3	68.7°	3	1,100	869	254	30	276	31.5	10	1	329	37.5	615	70	
4	70°	1	500	394	266	67	8	2	17	5	103	26	128	33	
5	79.5°	1	780	551	117	21	189	34.5	2	0.5	243	44	434	79	Seed was fed on to belt irregularly.
6	80.5°	2	550	443	2	0.5	265	60	0	0	176	39.5	441	99.5	Seed fed on to belt in thin layer.
7	81.7°	2	500	399	239	60	18	4	0	0	142	36	160	40	— — — thick —

About 1 kela of seed was used for each trial; from this quantity of treated seed the double seeds were picked out for examination.

system and one most easily controllable. Mr. H. C. Jefferys, Consulting Agricultural Engineer to the State Domains took this matter up as a practical proposition, a grant of money was obtained from the Administration and the matter was placed in the hands of Monsieur Crovisier, Engineer to the State Domains Administration, Sakha estate., to work out. M. Crovisier constructed a rough preliminary working model embodying the main ideas and principals of a machine suitable for subjecting infested cotton seed to heat treatment on the lines indicated above.

The machine consisted of a double-walled wooden chamber with a radiator lying along the bottom. The radiator was formed by a number of steam pipes connected up to the boiler of a portable engine. Above the radiator was an endless band or belt of cotton cloth passing over a series of rollers. In this particular machine the belt passed out of the machine at one end through baffle plates of a kind and was carried right underneath to the back end where it again entered. This of course was a defect as the belt lost a great deal of heat in passing through the outside air.

The cotton seed was fed on to the belt at one end by means of a hopper with a grooved roller working in the bottom above the outlet.

The speed of the seed carrying belt and thus the time the seed was exposed to the effects of heat could be varied at will. This facility was obtained by driving the main pulley of the belt rollers off the headstock gearing of a lathe, the latter being worked off a shaft pulley in the workshop in which the machine had been set up. The temperature was observed by a thermometer passing through the top of the chamber, the mercury bulb being just clear of the travelling belt. The temperature was regulated by a system of ventilators and the amount of steam passing through the radiator.

Table LIX shows some results which were obtained with this machine in trials carried out by M. Crovisier and the writer. About 1 kela (3.6 gallons) of seed were used for each trial and from this quantity all the «double seeds» were picked for examination in order to see the effect of the treatment on the pink bollworm. It will be seen that with an air temperature of 62° C. and an exposure of 7 minutes all the pink bollworms

were destroyed. Two minutes at 80° C. was almost equally successful if the seed was fed into the travelling belt in a thin layer, but when the seed was in a thick layer a totally different result was obtained. It is evident that the question of the quantity of the seed fed into the belt is a most important one, but at the same time the regulation of which presents no insurmountable difficulties to the engineer.

In addition to the unreliability of the seed-feed on to the belt, the most obvious point for criticism as regards the machine was the small quantity of seed which could be treated per hour. It must not be forgotten, however, that it was but in the nature of an experiment and the experience gained with what after all was a very rough and ready preliminary working model enabled M. Crovisier to plan another machine with which large quantities of seed could be treated, by increasing the number and area of the travelling belts. The alternate belts would move in opposite directions, the seed falling on to each successively without leaving the interior of the machine. By this means the speed of each belt would be increased very considerably, thus adding to the output of treated seed per hour. Temperature control was so planned that a definite degree of heat for the interior of the machine could be decided on and maintained constant by automatic means. On leaving the machine the seed would, if necessary, pass through a cooling chamber where it would be cooled down to air temperature, by means of currents of air from rotary fans, before entering the cleaning and separating machinery after which it would be sacked as usual.

Unfortunately owing to the outbreak of war and the absence of M. Crovisier with the French Army, this second and improved machine never materialized. But in the opinion of the writer such a machine is quite practicable and would be capable of dealing with a large output of seed if constructed of sufficient dimensions.

It must however be pointed out that not only would the first cost of a machine of this nature constructed on a scale to deal with the output of seed from a large ginnery be high, but the working expenses might also be heavy. To drive a large series of wide travelling belts would need a

considerable horse power, an in addition there is the steam necessary for heating the machine, although exhaust steam might perhaps be used for this purpose, or even the hot air and gases from the flues or chimney of the main boilers might be utilized. The cost of lubricating oil would not be a negligible item and the cost of repairs — inseparable from a machine with many bearings, wide seed carrying belts and belt driven pulleys — would tend to be heavy.

Although a machine for treating the cotton seed with heat in order to kill the pink bollworm has the advantage of being perfectly safe to run, there being no risk of fire, explosions, or the killing of people by the gases employed as is quite possible with fumigation unless proper care is exercised, it is not improbable that fumigation will be the method more generally adopted for treating the seed in Egypt, because of the advantage it appears to possess of being comparatively cheap both as regards the first cost of the necessary apparatus and the actual cost of treating seed per ton.

II. — TREATMENT OF THE SEED BY FUMIGATION.

It has been pointed out already that the chief working difficulty attached to the use of two gases most suitable for fumigation is their low power of penetration, the diffusion of both carbon bisulphide and hydrocyanic acid gas being far too slow through a mass of cotton seed for practical purposes. This difficulty has now been got over.

As regards Egypt, the first great advance in this direction was made by the Entomological Department of the Ministry of Agriculture with an apparatus for treating large bulks of cotton seed with carbon bisulphide. This machine and its working is fully described by Dr. Gough and Mr. G. Storey, Entomologists to the Ministry of Agriculture, in «Methods for the Destruction of the Pink Bollworm» [61], and it will suffice to say here that the apparatus consists essentially of a series of air tight seed containers connected with a vapouriser or carburettor for vapourising the carbon bisulphide and an air pump for circulating this gas through the cotton seed. It is said that hydrocyanic acid gas may be used in the place of the

carbon bisulphide, but in this case the machine has to be provided with a special generator.

The seed is filled in at the top of the container and when full the latter is closed by an air-tight door, and air is then drawn out at the top by means of the pump and, the carburettor having meanwhile been set to work, carbon bisulphide vapour mixed with air is then drawn in at the botton of the container through a perforated plate (the botton being double) and up through the seeds until finally the pure air has been replaced by a mixture of air and the carbon bisulphide gas. This is allowed to act for half an hour or some specified time. In practice one or more containers will be filling with untreated seed, in others the carbon bisulphide and air will be circulating, in others the seed will be resting exposed to the effects of the gas, and the last group will be in process of being emptied of their charge of treated seed.

All the containers are connected one with another by pipes and to the pump and carburettor by main pipes. By this system the carbon bisulphide charge can be pumped from a treated charge of seed into a container containing an untreated charge of seed, thereby affecting an important economy.

The treated seed is taken out at the botton of the container, falling by gravity through an opening, controlled at will, into sacks.

It is said that large quantities of seed can be dealt with per day by this method, assuming that an exposure of half an hour to the carbon bisulphide vapour is fatal to the resting pink bollworms in the seed. Whether this period will ultimately prove to be sufficient in practice when large bulks of seed are being dealt with remains to be proved apparently. It is possible that the time of the year when fumigation is carried out may be of importance, as during the winter when the larvæ are most sluggish, fumigation might be less effective than when the temperature is higher and the vitality or activity of the larvæ is greater. The killing power of carbon bisulphide is affected by temperature, more being required at a low temperature to obtain the same result than at a high temperature.

Although by this method the difficulty of the low penetrative power of

carbon bisulphide gas appears to be in a large measure got over, it by no means does away with the other disadvantages attached to its use and which have already been enumerated. Moreover, owing to the construction of the apparatus with its intricate system of pipes and taps the possibilities of leakages and consequently for accidents to occur, would seem to be considerable under everyday working conditions, more especially if the gas is under pressure. The question of leakages, however, will have to be considered in all forms of «gassing» machinery for treating cotton seed. Another point which must be given consideration and which applies both to apparatus for treating seed by fumigation or gassing and by exposure to heat, is the facility with which such machinery can be cleared off all seeds when the ginnery has been temporarily stopped for cleaning down before commencing the ginning of a different variety of cotton. It is essential that the cleaning process shall be capable of being quickly and thoroughly accomplished. Thus the machinery in which seeds are least likely to be held up or trapped will have an advantage.

The cost of the necessary quantity of carbon bisulphide and labour for treating each ardeb of cotton seed is likely to be fairly high.

Quite recently a further advance has been made in fumigating cotton seed, this time with hydrocyanic gas as the killing agent. Although the latter is far more deadly to human life than carbon bisulphide it is not inflammable or explosive (or only under exceptional conditions) and therefore its use about buildings is not objected to by fire insurance companies. Moreover, it seems unlikely that it will have any ill effects on the oil or cotton seed cake made from treated seed.

The improved method of using this gas consists of placing the seed in a container from which all the air is then removed by means of a vacuum pump. The hydrocyanic gas is then generated in a generator and at once allowed to rush in through a wide bored tap into the container and to take the place of the air. In this manner the gas not only very quickly penetrates through all parts of the seed, but it also diffuses rapidly into the seeds and through the cocoons inhabited by the pink bollworms, which succumb to its effects in a short time.

The great efficiency of this method of employing hydrocyanic acid gas for fumigating seeds appears to have been demonstrated first in America by Sasscer and Hawkins [62] and in Egypt by Mr. Victor Mosseri adapting and improving the system to the needs of fumigating cotton seed on a large scale.

Mr. Victor Mosseri, to whom I would here express my sincere thanks, has kindly given me the following note on this system as suitable for use in this country.

A NOTE ON THE FUMIGATION OF COTTON SEED

BY

M[a] VICTOR MOSSERI.

In general the larvæ of the Pink Bollworm are just as sensible to our ordinary means of destruction as the larvæ of other insects. Nevertheless the struggle becomes more difficult when it is necessary to combat this insect in the seed. In this case usual mechanical or chemical remedies lose singularly some of their efficacy.

In order to attain the object, one is obliged to increase to a great extent the intensity of the destructive agents and considerably prolong the period of their action. This could not be objected to if it were possible to treat infected seed alone, but as sound seed, whose germinating power must not be impaired, is inseparable from the infected seed, limitations are put upon the method of treatment. It must not be forgotten also that cotton seed supplies oil and cake and that it is necessary that any treatment it should undergo should never alter the qualities of these products nor render them unfit for consumption by man (oil), or cattle (cake).

No remedy can therefore be recommended where the necessary dose for killing the worm in the seed is prejudicial to the sound seed. In addition to these technical considerations there are also others of economical importance. As over four millions of qantars of cotton seed have to be treated annually within a comparatively short time (October to April), the process of destruction must be both quick and inexpensive. The remedy must not also present any serious danger in its manipulation.

This is how the problem of the struggle against the *Gelechia* sheltered in the seed is put forward.

The research work of the Ministry of Agriculture as well as that of the Sultanic Agricultural Society and our own, has demonstrated that, in principle, dry heat, carbon bisulphide and hydrocyanic acid gas are alone efficacious to meet the requirements of the case. However the employment of these remedies for considerable quantities of seed creates serious obstacles.

Without entering into lengthened details it will suffice to say that the obstacles referred to are due to the difficulties experienced in the penetrative power of the destructive

agents into the hollow seeds containing the larvæ. When hydrocyanic acid gas or carbon bisulphide is used, their diffusion through the silken covering to the hole by which the insect has entered the seed, is indeed, very slow. This renders necessary the use of large doses, the action of which must be maintained for a sufficient length of time to ensure penetration.

Even under these circumstances the results are often uncertain and discordant.

As regards the heat treatment, the penetration of the heat into the seed is not obtained more easily, especially with seed of the 2nd or 3rd picking, and «Mabrouma» seed to which a lot of fibre adheres. It is known that fibrous substances such as cotton offer great resistence to the diffusion of heat by conductibility, because they suppress the diffusion by convection in the air mass which they contain in their interstices.

In order to overcome these difficulties one could follow processes employed in certain branches of industry, especially those used for treatment of wood with preservatives, that is to say one could have thought of making a vacuum in the mass of seed to be treated before the application of the destructive agents. But I must sincerely add that such a method did not appear to me really susceptible of solving the problem of the struggle against the pink bollworm, until my attention was drawn by the excellent results recently obtained in America, in the struggle against the various granivorous insects (Sasscer and Hawkins; a method of fumigating of seeds — Bul. No. 186, U.S.A. Dep. of Agriculture, Feb. 1915).

A series of researches which it is useless to develop here, have enabled me to ascertain that vacuum permits the almost instantaneous diffusion of poisonous agents into the holes in infected seeds and renders the insect much more sensible to the effect of these agents; these two actions are practically explained by a considerable diminution of the doses which should be employed, by a sensible reduction of the period of treatment, and lastly by a greater certainty and a greater uniformity in the results. I was able to ascertain also that dry heat administered after a vacuum had been made caused the death of the larvæ at a less high temperature and in a shorter time than under ordinary pressure.

I have tried the action of dry heat, of carbon bisulphide, and finally the action of hydrocyanic acid gas after having previously made a vacuum in the mass of seed to be treated. Of these three agents I only wish to refer here to the last, that is to say hydrocyanic acid gas. This gas has gained the approval of American entomologists and mine also.

The laboratory experiments which I have made have shown that a dose af about $1\frac{1}{2}$ % in volume of hydrocyanic acid gas with a vacuum of 690 to 710 millimetres kills all the larvæ in the single or double seeds in about thirty minutes. This period varies somewhat according to the surrounding temperature, the seed mass, its state, the mode of gas distribution, etc.

It is very easy to regulate the dose or the period according to circumstances. By increasing the dose, one reduces the period.

Thus with about 3 % in volume of hydrocyanic acid gas, the necessary period does not exceed 15 to 20 minutes. I need not give here the figures of these experiments.

Practical demonstrations of this system have been made on various occasions. Amongst others, a demonstration was made in May 1915 before His Highness the Sultan, and in June of the same year before H. E. the Minister of Agriculture assisted by his technical staff and certain representatives of the principal cotton ginners in Egypt. These demonstrations have clearly proved the efficacity and practicability of the process which I recommend for the destruction of the larvæ of the pink bollworm in the infected seed, without

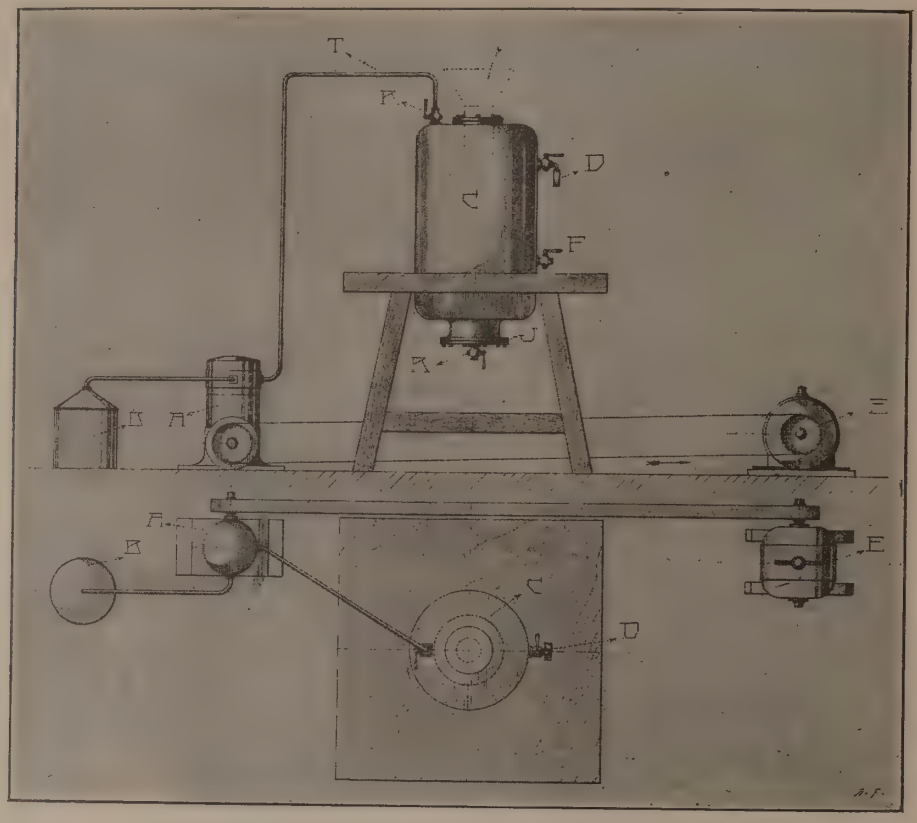

Fig. 16. — Demonstration apparatus used for the fumigation of cotton seed with hydrocyanic acid gas by the vacuum method.

altering the germinating power of the sound seed. Time not permitting I had to content myself for these demonstrations with a rudimentary installation sufficient however to give an exact idea of the system and to permit the necessary experiments being undertaken.

The apparatus I used consisted of a vertical cylindrical vat of about 300 litres capacity «C» with two orifices one in the upper part for filling and the other on the lower part for the discharge of the seed.

Simple cast iron covers were used for closing each of these orifices. Klingerite joints made the vat air-tight. The lower lid carried a tap «R» permitting the connexion of the cylinder «C» with the generator of hydrocyanic acid gas (an Erlenmayer flask). The

upper part of the cylinder was connected to a vacuum pump «A» similar to those which are used for centrifugal lift pumps. This pump was driven by an electric motor «E». It produced 690 millimetres of vacuum as a maximum. The discharge of the air exhausted from «C» was made into a small tank «B» filled with a solution of soda or potash through which it was permitted to bubble.

A manometer «D» placed also on the upper part of cylinder «C» showed the degree of vacuum attained.

In working, the seed was introduced into the cylinder «C» which was afterwards hermetically closed, vacuum was then made therein. Within a few minutes the manometer marked 680 to 690 millimetres (the maximum obtainable with the pump used). This vacuum was maintained 3 or 4 minutes, after which the upper tap «R» was closed. Hydrocyanic acid gas was then produced in the generator (Erlenmayer flask) with potassium cyanide and sulphuric acid according to the formula 1.1.3., after which the neck of the flask was attached to the lower tap «R'» by means of rubber tubing and the tap opened. The gas thus produced remained 20 to 40 minutes in the cylinder according to whether 50 or 100 grammes of potassium cyanide per cubic metre of seed was used. At the end of this time, pump «A» was again set in motion to withdraw the gas and eject it into the soda or potash solution contained in the bubbling tank «B».

The air tap «F» was then opened and only closed when the manometer fell to 0. Vacuum was made again. This operation being carried out once or twice before the discharge of the seed. In this way most of the remaining gas was removed. Guaiacum paper has shown that during all these manipulations there was no fear of any hydrocyanic acid gas emanations around the apparatus.

Tests have shown that the treated seed had lost nothing of its germinating property. In many tests, treated seed germinated better. Analyses of the treated seed have shown that if the vacuum is not made at the end of the treatment, there remained as much as ten or even twenty milligrammes of hydrocyanic acid (HCN) per kilogramme, according to the doses of the acid employed; but if a vacuum is made at the end of the treatment the retained HCN is considerably reduced, especially if the seed is given 2 or 3 washings with air.

Seed treated in this manner with single and double doses and pressed by the Egyptian Salt and Soda Co., for the extraction of oil, gave oil in which no trace of hydrocyanic acid could be detected, and cake with only insignificant traces of this acid.

In the experiments made with the apparatus described above it was found that an even diffusion of the gas through the seed mass was not easily obtained. The larvæ in the seed of the lower layers were more quickly killed. This was, no doubt, due to the mode of distribution of the gas and to the fact that this gas was mixed with a large quantity of moisture.

These experiments have been made in presence of Mr. F. C. Willcocks and I take the opportunity to tender to him my thanks for the interest he has taken in my work as well as for his assistance, and for the numerous examinations of larvæ he has kindly made for me.

Just as it is, the apparatus I have used cannot be utilized for installations in the ginneries without certain modifications being made in connexion with the opening and closing of the cylinders, the generating apparatus of the hydrocyanic acid gas, the mode of distribution of the gas in the mass of seed to be fumigated, the recovery of this gas or its destruction, and the protection of the apparatus against its corrosive action, etc.

The Egyptian Government having in consequence of these demonstrations, considered that this system recommended by me may be advantageously adopted for the general fumigation of cotton seed, decided to give me the opportunity of studying the various points in suspense, and at the same time the efficacity and the practicability of the said process on a commercial scale, by erecting at its own expense in Messrs. Choremi Benachi's Cotton Ginnery at Kafr Zayat the necessary apparatus, according to specifications made by me for the treatment of seed turned out from 70 gins, i.e. 1000 ardebs per day.

This installation will be considered as an experimental one, destined to decide the exact value of the new process, the cost of treatment as well as the action of hydrocyanic acid gas on the commercial value of seed and its products (cakes and oil).

A complete determination of the effect of the treatment on the cake and oil cannot be made until fumigated seed is turned out upon a sufficient large scale to permit feeding tests to be made, although analyses of small quantities made by three different authorities have clearly shown that no fear need be entertained.

July 1915. Victor Mosseri.

DIRECT MEASURES FOR THE CONTROL OF THE PINK BOLLWORM.

At present we have no suitable direct means of attacking and destroying the pink bollworm when once it has established itself in a field of cotton. This, however, is not surprising considering the fact that during a large and the most important part of its life the pest is efficiently protected inside the unripe bolls. The eggs being very minute and scattered cannot of course be collected, nor is it practicable for many reasons to destroy them by other means. Similarly the pupa stage is safe from attack. Control operations of a direct nature can only be attempted against this insect in its first larval stage or again when it has reached the adult or moth stage. However, as a matter of fact there appears to be little hope of much success attending efforts in this direction with the exception, perhaps, of trapping the moths. Thus, as already pointed out, it is on preventive measures that we must rely to control the pink bollworm.

We will now briefly examine the possibilities of some of the most obvious direct measures which may be tried for the destruction of the pest in the field.

THE USE OF ARSENICAL POISONS FOR CONTROLLING THE PINK BOLLWORM.

We know that many eggs of the pink bollworm moth are laid on the foliage of the cotton plants and it is probable that the young larvæ on hatching from these eggs may just at first feed on the leaves before entering the bolls. This habit to some extent lays the pest open to an attack with arsenical poisons, since if the plants were thoroughly and evenly sprayed with arsenate of lead no doubt a great many young larvæ would succumb to their first meal of leaf and arsenic. On the other hand, the large number of larvæ hatching from ova laid directly on the bolls would no doubt escape the effects of the spraying almost entirely, owing to the fact that the boll is in a large but varying measure protected from the spray by the enveloping involucre. This fact coupled with the probability that many of the larvæ arising from eggs laid on the leaves may abstain from feeding until they find a boll or square renders spraying at the best but a half measure — if that even.

Owing to the gradual emergence of moths from the resting larvæ of the previous year, several applications of the arsenate of lead would be necessary — at least one in June, July and again in August. But in the latter month thorough spraying of cotton would be, in many parts of Egypt, almost impossible owing to the size and closeness of the plants. Moreover, at this time of the year there is a serious risk of causing injury to the bolls and flowers by moving about too much in the fields. In the north of the Delta, where the plants run smaller, spraying would be possible in July, and perhaps also in the beginning of August; but in the south this would not be the case at all generally.

In addition to these difficulties there are many others to be met with as regards spraying in Egypt, and although for use against certain pests

this form of insect control may be quite suitable and under certain conditions quite practicable, yet for the control of the ravages of the pink bollworm the method seems to hold out no or but very slender hopes of being of benefit. It will, however, be interesting to carry out actual experiments to obtain precise information on the effects of arsenical sprays when used against the pink bollworm.

TRAPPING THE MOTHS OF THE PINK BOLLWORM.

Lamp traps. — In October 1913, experiments were made by the writer with an ordinary form of Lamp Trap (Plate X, Fig. 4) for destroying the moth of the pink bollworm, since if a large proportion of the moths could be caught before they had laid their eggs it follows that the severity of the attack would be greatly reduced. A full report on this work has been presented to the Cotton Worm and Bollworm Commission, but it has not yet been published.

It was found that the males and females of *G. gossypiella* came quite readily to light; of the total catch of 5,856 moths, 58 per cent were males and 42 per cent females. As regards the condition of the latter, about 65 per cent contained large numbers of eggs, but included in this figure are females which had laid part of their eggs previous to capture.

For this system to be effective it appeared that at least twenty or perhaps more than this number of low power lamps — the only lamp suitable for general use in Egypt — would be required per feddan. The practical difficulty and expense of working so many traps during July, August, September and perhaps also October would be very great and sufficient, I am afraid, to discourage most growers from practising this system. The number of lamps might perhaps be reduced if powerful lights were used, but these are expensive and are quite beyond the means of the majority of cotton growers. Trapping would have to be done over large areas to be of benefit.

Bait traps. — The pink bollworm moth is attracted to sweet fermented

liquids — such as fermenting beer and molasses, but to what extent these may be employed for trapping this species has yet to be learnt, very few trials having so far been made in this direction.

Attraction of water for the moths. — In the laboratory where at times large numbers of moths have emerged free from cotton seed, etc., it has been noted that water appears to have a great attraction for them, large numbers being drowned in dishes of water used to keep ants away from various objects. Possibly the moths might be trapped in the field in a similar way — the dishes of water or, better still perhaps, fermented molasses, « buza » (a kind of beer) and water, being distributed about the fields on wooden stands; but the use of such comparatively expensive substances as molasses and buza is practically impossible in Egypt owing to the rapidity with which they dry up by evaporation in open trays, and in consequence the high cost of renewing them at very short intervals.

CONTROL OF THE PINK BOLLWORM BY HAND PICKING THE EARLY ATTACKED GREEN BOLLS.

It has been suggested (Circular No. 55, Ministry of Agriculture) that it is a good plan to pick off the first green bolls attacked by the pink bollworm, in July and August, with a view to reducing the injury which will follow later on if these larvæ are left to increase. If this measure were practicable beneficial results would no doubt follow the destruction of the pink bollworms in the field at this period, but there seem to be numerous disadvantages which render its value very doubtful. These disadvantages are :—

I. — Cultivators object — unless absolutely compelled to do so by a severe attack of what may perhaps be called a spectacular pest readily seen and understood such as the cotton worm (*Prodenia litura*) — to tramp about amongst their cotton when the bolls have formed or are forming.

II. — The strains and stresses the bolls would be subjected to in

handling by the men and women or children looking for signs of attack by the pink bollworm might result in severe boll-shedding.

III. — The entrance hole made by the pink bollworm is so small as to be almost invisible; for this reason as many infested bolls would be left on the plants as picked, and furthermore, it is not improbable that a large number of perfectly sound bolls would be removed owing to spots being mistaken for the entrance hole of a bollworm by the pickers.

IV. — The labour and expense of examining the bolls one by one would be very large where such work has to be paid for.

V. — Practically speaking, one cannot tell if a green boll is or has been infested with the pink bollworm or not, unless a round hole is visible in the shell. This is the exit hole and generally indicates that the pink bollworm has left the boll. To pick these bolls in July and August would do little good and much harm, because you do not destroy a bollworm in 50 % of the cases (see Table XXVII), but you do destroy a first picking boll which in spite of having been attacked will in many cases give almost the normal quantity of fibre of quite good quality. One could of course, as suggested in the circular, dry the picked bolls in an oven and thus obtain a certain quantity of fibre of little value.

CEASING TO WATER COTTON AT AN EARLY DATE AS A MEANS OF REDUCING BOLLWORM INJURY.

One of Egypt's premier cultivators, His Excellency Badrawi Pasha, practices the following method of controlling the pink bollworm and the ordinary bollworm *Earias insulana*. Watering of the cotton is stopped after the middle or end of August, and by this method it is supposed that a crop much more free from bollworm attack is obtained. The reason for this would appear to be that owing to lack of water bolls ripen more quickly — although at the expense of quality if not the quantity of fibre as well — than they do if large quantities of water are given up to the usual dates, and thus an earlier and heavier first picking is obtained.

However, this method does not appear to result in a smaller number of the green bolls which remain on the plants after the first picking being attacked, and thus it can hardly be said to effectively reduce the numbers of the pest.

Through the courtesy of H.E. Badrawi Pasha we were able to examine bolls from his fields which had been treated according to his practice and bolls from the fields of tenants on his estate whose cotton had been watered up to a much later date. The results of this examination are given in Table LX.

INSECTS LIABLE TO BE CONFUSED WITH THE PINK BOLLWORM.

THE COTTON BOLL PYRODERCES.

Pyroderces simplex, Wlsm.

The larvæ of this little Tineid moth are very common during the autumn and winter months in cotton bolls which have been injured by the two bollworms *Gelechia gossypiella* and *Earias insulana*, and since they are pink or a reddish-pink in colour might be and no doubt are frequently mistaken for small pink bollworms.

DESCRIPTION, LIFE-HISTORY AND HABITS.

The egg. — The eggs of *Pyroderces* are very minute, oval, convex bodies, measuring about 0.36 mm. long by 0.22 mm. wide. the shell is longitudinally striated. They are laid on the damaged ripe bolls and the exposed parts of the interior.

The larva. — The larvæ feed on the injured seeds and fibre and general debris to be found in bolls which have been attacked by bollworms. At first the larvæ are white with a brownish head; later and whilst still quite small they may become pinkish or sometimes they

Table LX.

The Effect on the Severity of the Pink Bollworm Attack of not Watering Cotton after September 1st.

LOCALITY.	NUMBER OF BOLLS EXAMINED.		STATE OF MATURITY OF THE CROP.						INJURY CAUSED BY THE PINK BOLLWORM.							PERCENTAGE OF BOLLS ATTACKED BY:	
									RIPE BOLLS.			PARTIALLY RIPE BOLLS.		GREEN BOLLS.			
	1 NUMBER OF PLANTS.	2 TOTAL NUMBER OF BOLLS ON (1).	NUMBER OF RIPE BOLLS ON (1).	PER CENT OF (2).	NUMBER OF PARTIALLY RIPE BOLLS ON (1).	PER CENT OF (2).	NUMBER OF GREEN BOLLS ON (1).	PER CENT OF (2).	PER CENT OF SOUND BOLLS.	PER CENT SLIGHTLY ATTACKED.	PER CENT BADLY ATTACKED.	PER CENT SOUND.	PER CENT ATTACKED.	PER CENT SOUND.	PER CENT ATTACKED.	THE PINK BOLLWORM *GELECHIA GOSSYPIELLA.*	THE ORDINARY BOLLWORM *EARIAS INSULANA.*
Estate of H. E. Badrawi Pasha, (Dreen — near Mansourah).... Cotton not watered after 15th August.	50	1,606	822	51	208	13	567	36	83	14	3	49	51	39	61	70	1
Estate of H. E. Badrawi Pasha.... Cotton not watered after September 1st.	10	271	166	61	22	8	83	31	80	15	5	55	45	39	61	73	4
Estate of H. E. Badrawi Pasha, Tenant's Land..... Cotton watered up to September 20th and later.	50	1,148	485	42	200	17	463	41	72	25	3	37	63	33	67	61	0.3
Estate of H. E. Badrawi Pasha, Tenant's Land..... Cotton not watered after September 15th.	10	181	66	36	13	7	103	57	76	21	3	70	30	72	28	72	0

Variety of cotton = Nubari. — Bolls picked September 27th.

will be found to be quite dark coloured owing to their having fed on dark coloured decayed matter which shows through the somewhat transparent skin; or again, the skin may be covered and thus discoloured by the spores of the black sooty-fungus frequently present in damaged cotton bolls late in the year. When fullgrown the larva (Plate VII, Fig. 9) measures some 7 to 8 mm. long by 1.5 mm. broad. The head is light yellowish-brown and the thoracic shield is of the same colour but paler. The body is pale or slightly yellowish with two conspicuous and very distinct reddish-pink transverse and narrow bars on the back of each segment. The transverse barrings are so distinct that this character alone serves to distinguish the *Pyroderces* larva from the pink bollworm, in which the reddish-pink colour is much more generally suffused over the dorsum; and moreover, *Gelechia* larvæ of the size of the *Pyroderces* larva are, generally speaking, still white or white with faint pink suffusions around the hair tubercles.

The pupa. — The pupa (Plate VII, Fig. 8) may be found in the damaged boll enclosed in a light cocoon of silk. It is smaller and less robust than the pupa of *Gelechia* and is of a different form as will be seen if the illustrations of the two species are compared. The pupa of the pink bollworm is hairy and has several small hooklets near the tip of the abdomen. These are not present on the *Pyroderces* pupa.

The moth. — (Plate VII, Fig. 7) is described by Walsingham[63] as follows :—

« *Antennæ* whitish fawn-colour, spotted with brownish fuscous above. *Palpi* divergent, recurved, slender; pale fawn-colour, apical joint slightly longer than the second, touched with fuscous above the middle and before its apex. *Haustellum* long, clothed with shining white scales throughout. *Head* fawn-colour; face slightly paler. Thorax fawn-colour, paler posteriorly; with a shining metallic iridescence on the under side. *Forewings* fawn-colour, with a slender outwardly curved transverse whitish streak at one fourth from the base, preceded by some fuscous scales, which tend to form a basal patch; some shining whitish scales with a lilac iridescence are continued from its lower end, along the dorsal margin to the base, and extend also outwardly along the dorsal margin; on the dorsal margin at

about half the wing length is a small, outwardly oblique spot of fuscous scales; at the extreme apex is a dark fuscous spot preceded by a few scattered paler fuscous scales, which are also to be found along the base of the cilia; cilia fawn-colour, inclining to greyish fawn about the anal angle. *Exp. al* 9-11 mm. *Hindwings* grey, with fawn-grey cilia. *Abdomen* cinerous. *Legs* pale fawn, inconspicuously banded with darker fawn."

When at rest the moth assumes the very characteristic pose shown by Fig. 17.

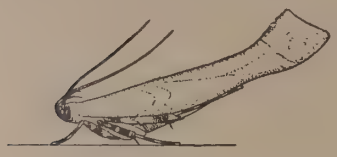

Fig. 17.
The moth *Pyroderces gossypiella* in characteristic resting attitude.

Seasonal history. — The seasonal history of this species is not well known. The winter seems to be passed chiefly in the larval stage in damaged cotton bolls and the seed capsules of teel and bamia which have been injured by *Gelechia* or *Earias* larvæ. These larvæ give rise to moths in April. Probably these moths again oviposit on any damaged bolls which may be available. *Pyroderces* larvæ have been found in the damaged bolls of the new crop as early as September and at about this season they may sometimes be found also in maize cobs feeding on the withered tassels.

THE HOLLYHOCK MOTH.

Crocidosema plebiana, Zell.

The Hollyhock Moth does not so far as we know attack cotton, but as its name infers it is found on the hollyhock (*Althæa sp.*). This ornamental plant may, in Egypt, also be attacked by the pink bollworm and thus it is possible that the two species might be confused in one or more of their stages when found on the same food plant.

DESCRIPTION AND LIFE-HISTORY.

The egg. — The eggs are laid singly on the seed capsules or fruits and the flower buds of the ornamental hollyhock (*Althæa sp.*). It is in this stage that the two species may be easily confused, their eggs being much alike. The egg of *Crocidosema* is slightly the larger, being 0.6 mm.

long by 0.36 mm. wide; it is oval in form, convex, and the shell is very rugose in appearance. The colour is pale at first and then a horseshoe-shaped irregular line of scarlet becomes visible and this may gradually spread until the whole egg becomes red or orange-red in colour. Before hatching the egg again becomes pale with dark spot at one end formed by the head of the young larva and a pinkish or reddish line along one side.

The larva. — The larvæ feed on the green unripe seeds or in the undeveloped flower buds. When full-grown the larva measures about 12 mm. in length and is green in colour with a brownish head.

The pupa. — The pupa (Plate VII, Fig. 6) is found in the damaged seed capsules. In general appearance it is not unlike the pupa of the pink bollworm, but with the aid of a magnifying glass it can be readily distinguished from the latter by the dorsal row of thorn-like projections on the basal margin of the abdominal segments and there is also a median row of these spines, but the latter are much smaller and less conspicuous than the others.

The moth. — The moth, a greyish or drab coloured insect, is illustrated on Plate VII, Fig. 5.

Seasonal history. — Nothing is known of the seasonal history of this insect and so far it has only been found to feed on the hollyhock *, having been taken in Cairo and at Sakha, in Gharbieh Province, on this food-plant.

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* I recently — July 1915 — found on a green cotton boll in the laboratory garden, Ghezireh, an egg which I believe to have belonged to *C. plebiana*. Unfortunately the larva died in the first or second stage — it did feed in a boll — so I have not been able to confirm the identity of the species. The young larva was very similar to a *Gelechia* larva but the hairs were simple and not dilated at tip. It will be necessary to follow the doings of this insect in case it should turn its attention to cotton.

Criptoblabes gnidiella.

This little moth has been bred from cotton bolls[64], but whether they attack sound bolls or only bolls previously injured by some other insect is not yet clear. We have bred this species from cotton bolls, castor oil plant, and in the autumn of 1914 it was common in maize, feeding on the unripe grains of those cobs which had been damaged by crows (*Corvus cornix*).

The eggs are unknown; the larva, which is figured on Plate VII, Fig. 3 is not likely to be confused with the pink bollworm, nor is the pupa stage (Plate VII, Fig. 4). The moth (Plate VII, Fig. 2) might perhaps be mistaken for *G. gossypiella* by a non-entomologist, but it is hoped that the illustrations will enable anyone to distinguish the two species in any stage.

INSECTS WHICH MAY BE ASSOCIATED WITH OR FOLLOW THE RESTING PINK BOLLWORM.

Two common insects, both members of the order Coleoptera or beetles have recently been observed to follow or be associated with the resting pink bollworm in ginned cotton seed and in damaged bolls. The first of these is the Cigarette Beetle (*Lasioderma serricorne*) which has been bred in tens of thousands from our breeding cages in which there were dead bolls damaged by the pink bollworm. They will also feed and breed in sacks of cotton seed infested with this pest. With the Cigarette Beetle one may also find numbers of one of its parasites — a handsome little metallic green Chalcid with dark thighs or femora and pale tibiæ.

A second common beetle found under the same conditions is the Flour Beetle (*Tribolium ferrugineum*), but whether this insect feeds on the damaged seed or the remains of dead larvæ, moths, and empty pupa cases is not yet clear.

There are other small Coleoptera which inhabit cotton bolls damaged by bollworms, no doubt feeding on the decayed matter and injured seeds. These have not yet been identified.

APPENDIX.

A NOTE

ON A POSSIBLE RELATION BETWEEN THE PINK BOLLWORM AND THE ORDINARY BOLLWORM *EARIAS INSULANA*.

It has been pointed out already and no doubt the fact will have been remarked by many observers that during the past three years of great activity on the part of the pink bollworm, the tendency has been, on the other hand, for the ordinary bollworm *Earias insulana* to become less and less numerous, and in consequence the injury caused by this species in 1913, 1914, and in 1915, has been very much less than it used to be in an average year before the advent of the pink bollworm in Egypt.

This rather sudden and noticeable change in the status of the *Earias* bollworm might be due to various causes or a combination of causes. It might be due for example to :—

I. To the abundance of a parasite or parasites.

II. To the more effectual carrying out of the law for pulling up the cotton, teel, and bamia plants at the end of the season and for suppressing the growth of these plants during the winter, since the Ministry of Agriculture installed its system of Inspectors in the Provinces.

III. That the Pink Bollworm itself is in some way prejudicial to the welfare of *Earias insulana*.

That No. I has been a cause to account for the comparative scarcity of *Earias* seems most unlikely, no marked increase in the numbers of any of its known parasites having been noted recently, in fact if anything, rather the reverse has been the case. But both Nos. II and III may, I think, have played an important part in bringing about the greatly lessened powers of injury now shown by *Earias insulana*.

As regards No. III : although it would seem improbable that there is a direct relation between the abundance of *Gelechia* and the scarcity of *Earias* in the sense that the one is antagonistic to and destroys the other;

Table LXI.

THE OCCURRENCE OF THE PINK BOLLWORM

1 YEAR.	2 NUMBER OF ATTACKED BOLLS EXAMINED.	3 NUMBER OF BOLLS CONTAINING PINK BOLLWORM ALONE.	4 PER CENT OF TOTAL (2).	5 NUMBER OF BOLLS CONTAINING *EARIAS* ALONE.	6 PER CENT OF TOTAL (2).	7 NUMBER OF BOLLS CONTAINING *EARIAS* AND PINK BOLLWORM.	8 PER CENT OF TOTAL (2).	9 NUMBER OF BOLLS CONTAINING 1 *EARIAS* AND 1 *GELECHIA*.	10 PER CENT OF TOTAL (7).
1913.....	2,402	1,618	67.36	84	3.49	83	3.45	39	47
1914.....	3,078	2,138	69.46	89	2.89	47	1.52	22	46.81
1915.....	1,345	898	66.76	20	1.48	29	2.15	14	48.27
TOTAL.....	6,825	4,654	68.19	193	2.82	159	2.32	75	47.17

yet on the other hand, that the pink bollworm may be indirectly inimical to the welfare of the *Earias* bollworm is by no means improbable.

That the pink bollworm is not directly concerned in this matter in that the larvæ of this species attack and kill the ordinary bollworms on meeting with them, seems probable because both species may be found living amicably, to all appearances, in the same boll. Table LXI shows the statistics we have on this question; the cases where the two species occur together are not very numerous naturally, owing to the scarcity of *Earias* and the great preponderance of the pink bollworm during the years in which records have been kept.

Again, the pink bollworm does not appear to be of a particularly combative nature for one may often find many of these larvæ living in the same boll, seemingly on good relations one with the other. It is true that if large numbers are placed together they will perhaps snap at each other, or seize hold of one another by the mandibles; another of their ways of showing irritation or annoyance appears to be to open wide the mandibles or biting jaws and to strike with them several times in rapid succession on the surface upon which they are at rest. However, I have not observed any tendency for those fierce struggles to take place in

AND *EARIAS INSULANA* IN THE SAME BOLL.

11 NUMBER OF BOLLS CONTAINING 1 *EARIAS* AND 2 *GELECHIA*.	12 PER CENT OF TOTAL (7).	13 NUMBER OF BOLLS CONTAINING 1 *EARIAS* AND 3 *GELECHIA*.	14 PER CENT OF TOTAL (7).	15 NUMBER OF BOLLS CONTAINING 1 *EARIAS* AND 4 *GELECHIA*.	16 PER CENT OF TOTAL (7).	17 NUMBER OF BOLLS CONTAINING 2 *EARIAS* AND 1 *GELECHIA*.	18 PER CENT OF TOTAL (7).	19 NUMBER OF BOLLS CONTAINING 2 *EARIAS* AND 2 *GELECHIA*.	20 PER CENT OF TOTAL (7).	21 NUMBER OF BOLLS CONTAINING 3 *EARIAS* AND 1 *GELECHIA*.	22 PER CENT OF TOTAL (7).
26	31.32	11	13.25	1	1.20	"	"	5	6.03	1	1.20
15	31.91	9	19.15	1	2.13	"	"	"	"	"	"
6	20.70	5	17.25	2	6.90	1	3.44	"	"	1	3.44
47	29.56	25	15.72	4	2.52	1	0.62	5	3.15	2	1.26

which the victor frequently finishes the combat by feeding on the vanquished, and which occur between individuals of a really cannibalistic type of larva or caterpillar, such as for example, the noctuid — *Agrotis ypsilon* or cutworm. One would think, moreover, that age for age the *Earias* larva should be quite capable of taking good care of itself, or at any rate of holding its own, in any encounter with a pink bollworm.

In India (Punjab) Maxwell-Lefroy [65] says that the pink bollworm and the two *Earias* bollworms *Earias insulana* and *E. fabia* (not found in Egypt) occur normally in about equal numbers, but that sometimes *E. insulana* is far and away the most numerous and injurious of the three species.

Now as regards the probability of there being an indirect relation between the *Gelechia* and the *Earias* bollworms in Egypt : such a relation might well be established in the following way.

The great damage caused by the pink bollworm during the past three years has, speaking in a general way, done away with not only a third picking of cotton, but also in many cases a normal second picking as well. One consequence of this upset has been to create a tendency for the

cotton plants to be pulled up at a much earlier date than usual. This would, in its turn, result in the cutting off, or at any rate reducing, the food supply and breeding ground of the ordinary bollworm *Earias insulana* at an earlier date too. This change would doubtless be a decided disadvantage to the latter species, since not only does it increase largely in the autumn bolls, but what is of still greater moment, is the fact that it is the late or November and December bolls which are most liable to form an important means for bridging the winter months and carrying the pest over well into the following spring. It is believed that moths emerging at this season will be, owing to their ability to live a long time in this stage, in a position to wait until the cotton is sufficiently advanced in growth to be attacked. This will be from mid-May or thereabouts (the date depending somewhat on the locality) onwards, the *Earias* larvæ being found at this period in the terminal part of the stem of the young cotton plants.

The following quotation from an unpublished report (written in the autumn of 1911) by the writer on the control of *Earias insulana*, will explain more fully why it is that the late green bolls are a danger where this species is concerned.

«However, it must be clearly understood, that if the terms of the Bollworm Decree are carried out conscientiously and completely by every farmer in Egypt, the effect will without doubt be to reduce to a very large extent the numbers and injuriousness of the bollworm in the following cotton season. Moreover, if farmers would only take a further and simple step which, however, may necessitate a little extra trouble and expense, the effectiveness of the cultural method of controlling the cotton bollworm (*Earias insulana*), as explained above and in the Khedivial Decree of 1909, would be doubled.

«In the ordinary course of events a vast quantity of this year's (1911) cotton plants will not be removed from the land until late in December and some perhaps not until after the end of December. On these cotton plants and also teel plants there will be many green bolls and buds, or in the case of teel, unripe seed capsules. Herein lies a grave danger since in these green bolls, etc., there will be bollworms — some quite small, others nearly full-grown — and on the outside there may be, in fact we may say will be unhatched eggs of the bollworm moth. The majority of those bollworms which are almost or quite full-grown when the cotton wood is stored in heaps in the fields or on the roofs of the houses will be able to complete their growth and will then leave the boll spin a cocoon of silk in some convenient situation and change to the pupa stage. In due course the moths will

emerge in February and early March. Providing no food plants — cotton, teel, etc., — have been left in the fields all, or at all events the majority of these moths will, it is believed, die before the new crop is in a stage to be attacked.

«But let us now examine the case of the bollworms which were quite small or not even hatched from the egg when the cotton plants were pulled up and stored. Although a very great number of these small bollworms will die on account of the drying up of the boll in which they are feeding; or if on this account they leave the boll and endeavour to find another, they may get lost in the search; or again, supposing they do find a boll, the shell may be too dry and hard on the outside for them to pierce it. On the other hand, other small bollworms more favourably situated will undoubtedly complete their growth and will be changing to the pupal stage in January or even in February. It is from bollworms which turn to the pupal stage at this period of the year that real danger is to be apprehended — fortunately their numbers are small. It may be mentioned here that if a boll of moderate size keeps green it will be quite sufficient for the food of a bollworm from the time it first enters the boll after emerging from the egg until it is full grown and ready to change to the pupal stage. A single green seed pod of the teel plant will suffice for one or even two bollworms during their whole life in this stage (worm stage). Bolls on plants which have been pulled up and stacked within a comparatively short time will keep green and soft inside for a considerable period.

«As has been stated above the danger of the bollworm pest — in small numbers only — bridging the gap between the end of one cotton season and the new crop lies in those bollworms which reach maturity and turn to pupæ amongst the stacks of cotton plants at or towards the end of January and in February. The moths from these pupæ will emerge towards the end of March or in April.

«We now come to the question of the length of life of the Bollworm moth — the parent of the bollworm. Unfortunately, the bollworm moth may be long-lived, it may live only a week or two, but on the other hand, it may live a month or even two months, that is judging from individuals kept in captivity under fairly natural conditions.

«Thus it will be readily understood that some moths which emerge in late March and early April may live until May when in many localities the cotton plants will be sufficiently grown for the female moth to lay eggs on the terminal bud of the stem. The bollworm on hatching from the egg bores into and lives inside the shoot.

«There is an important point with regard to the life of the bollworm moth, which may tend to reduce the danger, viz. the later the moths emerge in the spring the shorter appears to be their life.

«Having explained that even if the Bollworm Decree is carried out to the letter that some moths will escape to lay eggs on the new crop in May, it thus becomes necessary to seek for some measures which will negative this danger or at any rate reduce the number of moths which escape to an absolute minimum.

«The solution of the problem obviously lies in two directions : firstly, we must destroy the bollworms which reach full growth in January and February by removing the bolls

and buds which harbour them before the plants are stored; and secondly, we must destroy the first bollworms which appear in the cotton in the month of May and June.»

Now, if owing both to the serious pink bollworm attack and the more strict application of the law for the control of the bollworm, the cotton plants are nowadays pulled up at a much earlier date, generally speaking and generally over the country or at any rate in Lower Egypt, *Earias* larvæ in the green bolls left on the plants will probably reach maturity at a date that, in spite of a longish pupal stage in the cold weather, will bring the moths out so early in the New Year that notwithstanding their longlivity, the chances will be that in the absence of food plants — and it is here that the more effectual carrying out of the Bollworm Laws, owing to the work of the Inspectors of the Ministry of Agriculture, may have had an important bearing on this question also — the moths will perish from some cause or another before the new cotton crop is in a condition to furnish food for their offspring.

If there really has been an earlier removal of the cotton plants at all generally over the country, and consequently a reduction in the number of green bolls available late in the season; then I think it would without doubt reduce the numbers of the «spring *Earias* bollworm moths» originating directly from these green bolls (not from bolls or seed capsules on any winter volunteer growths of their food plants) available to renew the attack on the cotton in May and June. The smaller the numbers of the pest in the fields at this season, the smaller will be the numbers, presumably, of their descendents in the autumn — September, October, and November, — the season when *Earias insulana* used to frequently cause very considerable harm to the second and third pickings of cotton fibre.

It must also be pointed out that the rapidity with which the green bolls are invaded and destroyed by the pink bollworm at this time of the year will also tend to reduce the green bolls available for *Earias* to feed and increase in. A rather interesting case, seemingly of this nature, was observed at Bahtim in 1914 and 1915. Last year (1914) from a cotton-sack full of bolls, which were removed from the plants just before they were pulled up towards the end of October, some five or six hundred

moths of *Earias insulana* were obtained. In this instance a large number of the bolls picked off were unripe and still quite green. This year (1915) although a much larger number of bolls were picked and brought into the laboratory very few bollworm moths were secured : all the bolls from one feddan (acre) of cotton were taken, these weighed 165 kilos and in this weight there were something in the neighbourhood of 80,000 bollworm damaged bolls, but amongst this large number only 46 green or unripe bolls were found! The consequence of this was that only about 50 *Earias* moths were obtained.

However, it cannot be positively asserted that this marked lack of green bolls was entirely due to the work of the pink bollworm, although if it were not this pest which had a good deal to do with the question, then it would be especially curious that there were so few unripe bolls on the plants at the end of October, since the crop (Assili cotton) was very late sown at Bahtim in 1915.

If further observations should definitely establish that there is a relation, such as put forward above, between the pink bollworm and *Earias insulana* it will be of considerable interest as a case of one pest exercising an indirect control on the increase and powers for injury of another pest. However this would not be the only case of its kind, for we find much the same thing occurs in America between two well-known pests — the Cotton Worm (*Alabama argillacea*, Hubn.) and the Mexican Cotton Boll Weevil (*Anthonomus grandis*, Boh.)[66]. The former pest by defoliating the cotton plants late in the season tends to drive the weevil out of the fields, and the removal of shade allows the sun to destroy numerous immature stages of the weevil in squares lying on the ground. It is stated that — «in fact, where defoliation is complete the boll weevil receives almost as serious a setback as happens when the planter destroys the cotton stalks in the fall (autumn)». If the cotton worm defoliates the cotton plants early in the season it is of course not beneficial, but injurious.

APPENDIX II.

NEW PUBLICATIONS ON THE PINK BOLLWORM.

A delay in the publication of this volume, owing to the coloured plates not having arrived from England, enables me to include in this Appendix mention of an interesting contribution to our knowledge of the pink bollworm which has appeared recently under the title of « The Nature of the Damage done by the Pink Bollworm »[67], by Lewis Gough, Ph. D., Director of the Entomological Section, Egyptian Ministry of Agriculture.

In this bulletin several interesting new points regarding the work of this pest are discussed. Dr. Gough has ascertained that *whole* or *un-pierced* seeds in bolls which have been injured by the pink bollworm, not only tend to be lighter in weight than whole seeds from sound un-attacked bolls, but also that they lose vitality or vigour, and consequently their germination power is affected, many failing to germinate altogether.

It was found also that the number of seeds present in attacked bolls was considerably less than the number of seeds in sound bolls. I also found a slight reduction in the number of seeds in attacked bolls (see Table VIII., pages 48-49) but omitted to refer to the matter in the text.

Dr. Gough also deals with another question of general interest — that of ginning out-turn as affected by the pink bollworm. Ginning out-turn, by the way, means the amount of ginned fibre obtained from a standard weight of seed-cotton : the amount of lint or fibre is frequently expressed as a percentage of 100 pounds of seed-cotton.

It was found that, contrary to expectations, the ginning out-turn of seed-cotton from attacked bolls of the second picking was reduced. But Dr. Gough points out that under ordinary factory conditions of ginning it would not unlikely be found that the out-turn on a sample which had been badly injured by pink bollworms would tend to be higher, owing to a lot of the light damaged seed, small seeds, empty hulls and broken pieces of seeds, being lost in the screenings from the seed cleaning machinery.

In order to definitely clear up this point we shall have to obtain figures from the factories. But whatever the difference, if any, that has been noted in the out-turns of Egyptian cottons since the advent of the pink bollworm in Egypt one would be led to expect one effect from the work of this pest, viz., that the proportion of scarto cotton will show an increase. This, however, will depend to some extent on the ginning.

As they may be of interest I give now in *Appendix IV* the ginning outturns for the produce of the bolls examined in Tables VIII and XV., pages 48-49 and 60 of this volume. These figures are not, however, comparable with those given by Gough; those in Table VIII being bolls of the first picking, and in Table XV *all* fibre is included for the bolls of the second picking : a considerable amount of the attacked fibre would never have found its way into a sample picked under ordinary field conditions, as were the second picking bolls examined by Dr. Gough.

Unfortunately my figures for the 1915 crop grown at Bahtim are not yet available for comparison with the 1914 figures, and so cannot be included.

Another publication on the pink bollworm which has only just come to my notice is a Circular issued by the United States Department of Agriculture entitled «The Pink Bollworm». This circular is quoted in the Agricultural News (Imperial Department of Agriculture for the West Indies) by H. A. B. under the heading «Insect Notes» The Pink Bollworm [68]. In this article the following interesting quotation is made from the circular mentioned.

«It would seem that the pink boll worm has been introduced into many new localities with, or in, cotton seed for planting. Examples of this are probably to be found in the Hawaiian Islands, in Egypt, and the several colonies in Africa where it is now well established. It has not yet been introduced into the United States, but in 1912 a shipment of 500 lb. of Egyptian cotton seed got as far as Arizona, where it was discovered to be infested by pink boll worm, and the whole shipment was destroyed by fire. Since then on several occasions the pink boll worm has been intercepted in shipments of cotton seed in the United States.

«On July 1, 1913, the Federal (U. S.) Horticultural Board promulgated a quarantine against cotton seed from all foreign countries, with the object of preventing the invasion of the pink boll worm. Since this quarantine has been in effect, several shipments of cotton seed have been intercepted. All were found to be infested by the pink boll worm; one shipment which was to be forwarded to Arizona, showed an infestation of 20 per cent.»

This experience illustrates in a striking manner the ease with which the pink bollworm can be introduced into new territory, and consequently the danger run by cotton growing or intending cotton growing countries in importing, from countries infested with the pink bollworm, cotton seed in quantities no matter how small and for any purpose, if such seed has not first been subjected to a treatment which will absolutely ensure the destruction of all pink bollworms it may contain before it leaves the country of origin.

APPENDIX III.

THE EFFECT OF INJURY BY THE PINK BOLLWORM ON THE GERMINATION OF COTTON SEED.

In the section dealing with the nature of the losses caused by the pink bollworm I failed to point out a fact which, however, is I think fairly obvious — viz., that cotton seeds which have been badly injured or holed by the larvæ will not germinate and thus are useless for sowing. Although some seeds which have had the seed-coat just pierced and the embryo just touched or only exposed may germinate under laboratory conditions; under field conditions, they will be very liable to fail owing to the risk they will run of being invaded at an early stage by the «Sore Shin Fungus», which will be able almost immediately to attack the embryo or young plant through the wound in the seed coat. Seed containing a large amount of damaged seeds should not of course be purchased for sowing, not only on account of the low germination capacity of such a sample, but also because of the large number of resting pink bollworms it is likely to harbour.

APPENDIX IV.

GINNING OUT-TURNS OF SOUND AND INJURED SEED-COTTON FROM BOLLS OF THE FIRST AND SECOND PICKING.

ASSILI COTTON, BAHTIM, 1914 CROP.

A. TABLE VIII., PAGES 48-49.

The ginning out-turns have in this table already been expressed in the form of a percentage. However, it will perhaps be better if I now bring them together expressed in the ordinary Egyptian way of so many rotls of lint per kantar of 315 rotls of unginned or seed-cotton. A rotl is 0.9905 of a pound avoirdupois.

a. Column 13. Seed-cotton from 230 *Sound Bolls* of the 1st Picking.
Weight of seed-cotton = 580 grams.
Weight of ginned fibre = 199.9601 grams.
Ginning Out-turn = *108.*

b. Column 18. Seed-cotton from 163 *Attacked Bolls* of the 1st Picking.
Weight of seed-cotton = 279.964 grams.
Weight of ginned fibre = 91.6338 grams.
Ginning Out-turn = *103.*

c. Column 24. *Sound Seed-cotton* from *Attacked Bolls* of the 1st Picking.
Weight of seed-cotton = 70.116 grams.
Weight of ginned fibre = 23.763 grams.
Ginning Out-turn = *107.*

d. Column 25. *Slightly Injured Seed-cotton* from *Attacked Bolls* of the 1st Picking.
Weight of seed-cotton = 139.418 grams.
Weight of ginned fibre = 46.9278 grams.
Ginning Out-turn = *106.*

e. Column 28. *Badly Injured Seed-cotton* from *Attacked Bolls* of the 1st Picking.

Weight of seed-cotton = 70.430 grams.
Weight of ginned fibre = 20.943 grams.
Ginning Out-turn = 94.

ab. Column 5. *All* Seed-cotton from 393 *Sound* and *Attacked Bolls* of the 1st Picking.

Weight of seed-cotton = 860.315 grams.
Weight of ginned fibre = 291.5939 grams.
Ginning Out-turn = 107.

B. TABLE XV., PAGE 60.

a. Total Seed-cotton from *Sound* and *Attacked Bolls* on 204 Assili Cotton Plants of the 1st Picking.

Weight of seed-cotton = 6,598 grams.
Weight of ginned fibre = 2,229 grams.
Ginning Out-turn = 106.5

b. Seed-cotton from *Sound* and *Attacked Bolls* of the *2nd Picking.*

Weight of seed-cotton = 423.55 grams.
Weight of ginned fibre = 150.75 grams.
Ginning Out-turn = 112.

Remarks. — 1st Picking.

1° It will be noticed that in this case the ginning out-turn of *sound* seed-cotton from *attacked bolls* is lowered.

2° It appears that the out-turn of injured seed-cotton from attacked bolls is reduced to a degree varying according to the severity of the injury. This result was not expected as it was thought that in the case of first picking bolls the fibre would suffer to a very much less extent than the seeds, and consequently there would be a tendency for the ginning out-turn to be higher.

Remarks. — 2nd Picking.

1° In the case of seed-cotton of the second picking from bolls on 48 cotton plants the ginning out-turn is high, being 112. But it must be pointed out that in this instance *all* fibre was included, and not only such fibre as would have been picked under normal field conditions. And again, the weighings were done some months after the cotton had been picked and so the seeds were well dried. This figure is of course given under all reserve, since at present it is unconfirmed by others, but at the same time a high out-turn for seed-cotton of our second picking was not altogether unexpected, since the seeds suffer very severely, a much larger number per boll being attacked in the second than in the first picking, and moreover, a large proportion of the injured seeds in second picking bolls are mere empty hulls. The fibre of course also suffers great injury, but speaking in a general way, although the quality of this fibre is shockingly bad there is often quite a fair amount of it surrounding the eaten-out seeds.

2° I consider that before we can be certain of the effect of the work of the pink bollworm on the ginning out-turn of the different pickings, it will be necessary to have figures for several years and for larger quantities of cotton than I have, in many cases, handled. There is also another matter which must not be overlooked : this is the presence or absence of Seed-Bugs (*Oxycarenus hyalinipennis*) in the bolls, especially the damaged bolls of the second picking. These insects pierce the seeds with their sucking mouths or beaks and extract the juices from the embryo; by so doing they not only cause light seed, but also tend to affect the germination power of the seeds. In the case of the second picking bolls from our cotton at Bahtim, seed-bugs were present but not, as is sometimes the case, in large numbers.

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EXPLANATION OF PLATES.

PLATE IV.

EXPLANATION OF PLATE IV.

All figures are, unless otherwise indicated, enlarged. The *hair-lines* indicate the approximate natural size of the insects illustrated.

Figures.

1. The Pink Bollworm Moth.
2. The egg of the Pink Bollworm Moth — 1st stage.
3. The egg of the Pink Bollworm Moth — 2nd stage, incubation advanced.
4. A Pink Bollworm newly hatched from the egg.
5. A second-stage Pink Bollworm.
6. A full-grown Pink Bollworm — dorsal view.
7. A full-grown Pink Bollworm — side view.
8. The pupa or chrysalis stage of the Pink Bollworm.
9. Resting Pink Bollworms spun up in small spherical cocoons in cotton fibre.
10. The pupal cocoon of the Pink Bollworm — note that it is long and oval in form.
11. A healthy ripe cotton boll — natural size.
12. A cotton boll — natural size — which has been badly injured by pink bollworms; it has produced no pickable fibre.
13. A «Mabrouma» cotton boll — natural size. This boll has been attacked by a pink bollworm, and it has ripened without opening and giving fibre.
14. The cocoon of a resting pink bollworm spun amongst the seeds of Bamia (*Hibiscus esculentus*). — Slightly enlarged.
15. A «double cotton seed» which harbours a resting pink bollworms. — Slightly enlarged.
16. Cotton seeds injured by pink bollworms. — Slightly enlarged.
17. A cocoon of a resting pink bollworm spun amongst Teel seeds (*Hibiscus cannabinus*). — Slightly enlarged.
18. A different view of N° 17.

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THE PINK BOLLWORM.

PLATE V.

EXPLANATION OF PLATE V.

All figures are, unless otherwise indicated, enlarged. The *hair-lines* indicate the approximate natural size of the insects illustrated.

Figures.

1. A healthy cotton flower — natural size.
2. A cotton flower which has been attacked by and harbours a pink bollworm. The latter lies under the spun together mass of dark coloured pollen. Note also the black specks amongst the stamens — the excrement of the larva and an indication of its presence. Drawing natural size.
3. An unripe cotton boll which has cracked prematurely owing to proliferation set up in the interior by the work of a pink bollworm. Drawing natural size.
4. A parasite — the Pink Bollworm Pimpla (*Pimpla roborator*, F). A female.
5. The male *Pimpla roborator*.
6. The egg of *Pimpla roborator*.
9. The full-grown larva of *Pimpla roborator*.
10. The pupa (female) of *Pimpla roborator*.
11. A Pink Bollworm with a young *P. roborator* larva feeding upon it.
12. A larva of *Pimpla roborator* ready to assume the pupal stage.
13. A Bethylid — a Parasite of the Pink Bollworm.
14. The Pink Bollworm Chelonella (*Chelonella sulcata*, Nees.) a parasite of the Pink Bollworm.
15. An Ichneumon Fly — *Limnerium interruptum*.

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THE „WORK AND NATURAL ENEMIES OF THE PINK BOLLWORM.

PLATE VI.

EXPLANATION OF PLATE VI.

All figures, unless otherwise indicated, are enlarged. The *hair-lines* indicate the approximate size of the insects illustrated.

Figures.

1. An unripe cotton boll infested with the pink bollworm.
2. An unripe cotton boll showing the first signs of invasion by the pink bollworm. Note the small discoloured areas at A.
3. An unripe cotton boll badly attacked by the pink bollworm.
4. The Small Pteromalid — a parasite of the resting pink bollworm in cotton seed. Female.
5. The Small Pteromalid — male sex.
6. The Egg of the Small Pteromalid.
7. The full-grown larva of the small Pteromalid.
8. The pupa of the Small Pteromalid.
9. A pink bollworm with the larvæ of the small Pteromalid feeding upon it.
10. The Triphleps (*Triphleps sp.*) — a small predaceous bug which destroys the eggs of the pink bollworm.
11. The nymph or pupa stage of the Triphleps.
12. The larva stage of the Triphleps.
13. The bollworm Braconid — *Rhogas kitcheneri* (female) — perhaps an occasional parasite of the pink bollworm, and a common parasite of the *Earias* bollworm (*Earias insulana*).

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THE WORK AND NATURAL ENEMIES OF THE PINK BOLLWORM.

PLATE VII.

EXPLANATION OF PLATE VII.

All figures are, unless otherwise indicated, enlarged. The *hair-lines* indicate the natural size of the insects illustrated.

Figures.

1. An unripe cotton boll in a state of proliferation. Note the appearance of the seeds and compare them with the seeds in boll Fig. 2, Plate VI.
2. A moth *Cryptoblabes gnidiella* which was bred from cotton bolls and which might be mistaken for the moth of the pink bollworm.
3. The larva of *C. gnidiella*.
4. The pupa of *C. gnidiella*.
5. The Hollyhock moth (*Crosidosema plebeiana*, Zell.) the larva of which feeds in the seed capsules of the hollyhock (*Althæa sp.*) and might be mistaken for a pink bollworm.
6. The pupa of the hollyhock moth.
7. *Pyroderces gossypiella*, a small moth the larva of which is sometimes confused with the pink bollworm.
8. The pupa of *Pyroderces gossypiella*.
9. The larva of *Pyroderces gossypiella*.
10. The male of *Rhogas kitcheneri*.
11. A pink bollworm infested with the predaceous mite *Pediculoides ventricosus*, Newport.
12. A mature female *Pediculoides ventricosus*.

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NATURAL ENEMIES AND INSECTS LIABLE TO BE CONFUSED WITH THE PINK BOLLWORM.

PLATE VIII.

EXPLANATION OF PLATE VIII.

The illustrations on this plate are about one half of the natural size.

Figures.

1. Sound ripe cotton bolls.
2. A ripe cotton boll showing one sound lock of fibre and two attacked and undeveloped locks.
3. A ripe cotton boll in which two locks have escaped injury by the pink bollworm.
4. Cotton bolls which have been attacked by the pink bollworm — the fibre has only partially developed.
5. A cotton boll which has been attacked; one lock fairly good, one pickable, and one ruined by the pink bollworm.
6. Bolls badly injured by the pink bollworm. They have produced no fibre.
7. Ditto.
8. Ditto.
9. A Mabrouma boll.
10. A Mabrouma boll which has just split apart, but the fibre has not fuzzed out.
11. Attacked bolls showing felted locks of Mabrum cotton.
12. A lock of seed-cotton from a sound cotton boll.
13. Mabrum locks of seed-cotton from bolls attacked and injured by pink bollworms.

The Work of the Pink Bollworm.

PLATE IX.

EXPLANATION OF PLATE IX.

Figures.

1. The large breeding cage used for 50,000 damaged cotton bolls infested with resting pink bollworms.
2. A sample of 3.956 kilos of Assili cotton, first-picking, grown at Bahtim in 1914, showing the quantity of badly damaged fibre in the small heap on the right.
3. A sample of 3.956 kilos of Assili cotton, second-picking, grown at Bahtim in 1914. Note the very large proportion of badly damaged fibre in the heap on the right.

Fig. 1

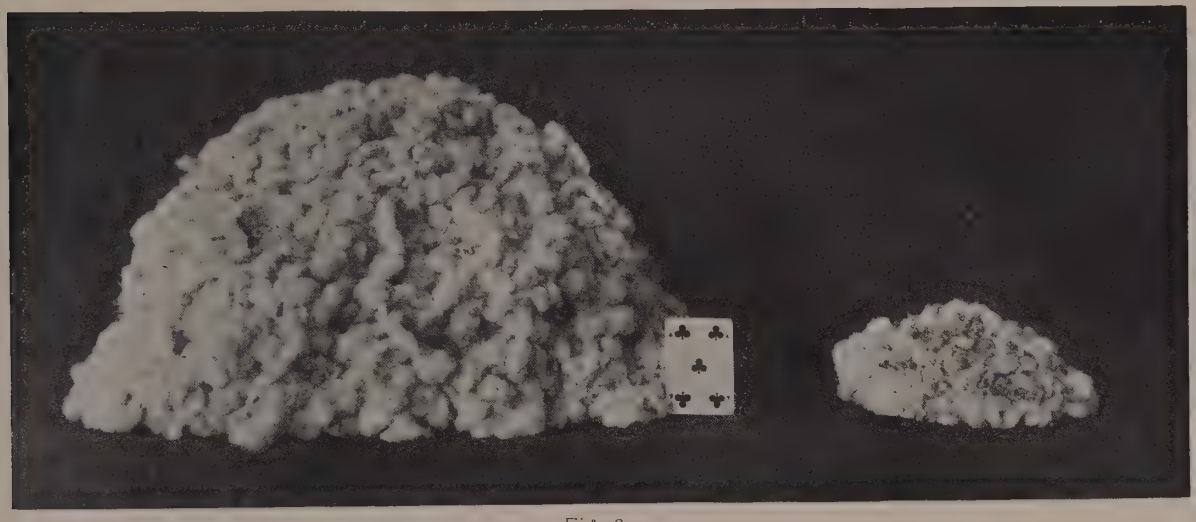

Fig. 2

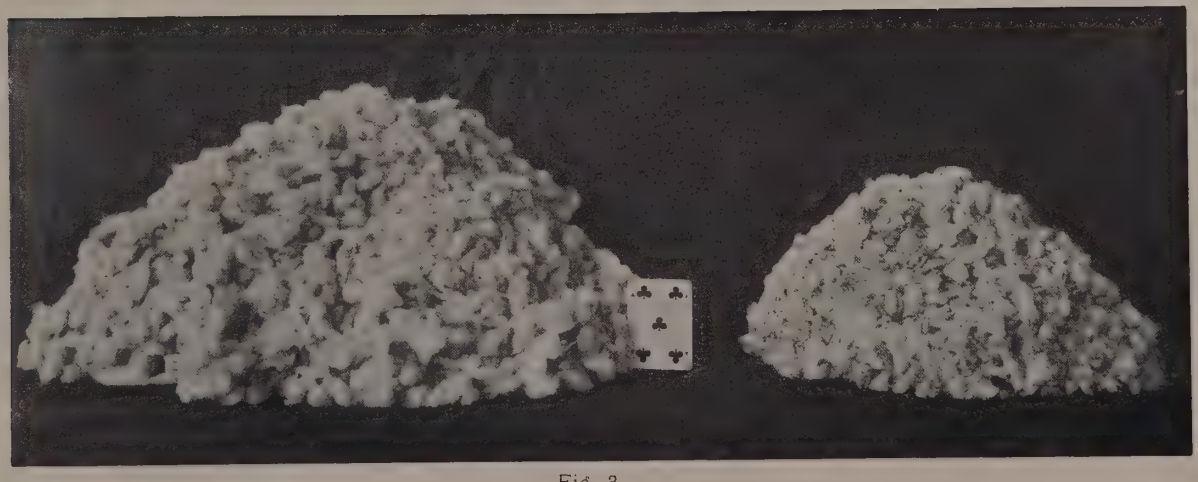

Fig. 3

PLATE X.

EXPLANATION OF PLATE X.

Figures.

1. Boll destruction. Sheep feeding on the leaves and bolls in a field of cotton after the last picking has been taken.
2. Part of the same field after the sheep have finished, the plants have been stripped bare.
3. A heap of cotton sticks — a most dangerous source of infection to the new crop, if the old bolls infested with resting pink bollworms have been left on the plants, and if the sticks are not burnt before April.
4. Cotton sticks and a carpet of broken pieces of sticks and old bollworm-damaged cotton bolls, still containing mabrum fibre and resting pink bollworms, in front of a pumping engine house. The engine has been fired with cotton wood. All bolls should of course be swept up and burnt, not allowed to accumulate as shown in the photograph.
5. Carting cotton sticks from a long wind-row on the bank of a canal. Many bolls get broken off and sifted down through the sticks on to the ground, into cracks, and amongst grass, etc. Handle cotton sticks with bolls on them as little as possible, and do not distribute them over a larger area than necessary.
6. A lamp trap for catching bollworm moths. This trap consists of an ordinary paraffin lamp standing in a zinc tray containing water with a little paraffin on the surface. The lamp and tray are supported on a wooden stand.
7. A female *Pimpla roborator* — the Ichneumon-Fly parasite of the pink bollworm — stinging a resting pink bollworm in a ripe but damaged cotton boll.
8. The same as (7) only the position of the Pimpla is slightly different. Note that the ovipositor proper is inserted in the boll; it is the ovipositor sheath only, which projects out behind from the end of the abdomen.

Fig. 1

Fig. 2

Fig. 3

Fig. 6

Fig. 4

Fig. 5

Fig. 7

Fig. 8